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SERIE: FISKERI · BIND IV

Nr. 1. A. C. Johansen: CONTRIBUTIONS TO THE BIOLOGY OF THE PLAICE WITH SPECIAL REGARD TO THE DANISH PLAICE-FISHERY. V. THE SUPPOSED MIGRATIONS OF PLAICE FROM THE KATTEGAT AND THE BELT SEA TO THE TRUE BALTIC

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CONTRIBUTIONS

TO

THE BIOLOGY OF THE PLAICE

WITH SPECIAL REGARD TO THE DANISH PLAICE-FISHERY

V

THE SUPPOSED MIGRATIONS OF PLAICE FROM THE KATTEGAT AND THE BELT SEA TO THE TRUE BALTIC

BY

A. C. JOHANSEN

KØBENHAVN
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I. Introduction.

In a newly published treatise "Biologische Untersuchungen über Gedeihen, Wanderung und Ort der Entstehung der Scholle (*Pleuronectes platessa*) in der Ostsee"[1] Professor J. Reibisch has called attention to a series of phenomena which according to his opinion indicate that great migrations of plaice take place from the Kattegat and the Belt Sea to the true Baltic. Professor Reibisch supports thus to a certain degree the old hypothesis of Dr. C. G. Joh. Petersen, that the stock of plaice in the true Baltic is not indigenous to this sea, but has immigrated from the Kattegat and Belt Sea[2].

Prof. Heincke[3], the author[4], and the Swedish "Hydrografisk-Biologiska Kommissionen"[5] (Messrs. G. Ekman, O. Pettersson and F. Trybom) have in the main differed from this hypothesis, and also Prof. Reibisch's new immigration hypothesis differs in many respects from the old one of Dr. Petersen. Thus he regards it as probable that a certain percentage of the part of the stock of plaice living in the area between the Gedser-Darsser Ridge and the line Arkona-Trelleborg is indigenous there, and that every year a certain quantity of plaice pass through the development from egg to bottom stage there. He expresses himself as follows: (p. 195—196)

"In dem Becken östlich von der Darsser Schwelle bis zu der Linie Arkona-Trelleborg sind die Verhältnisse für die Entwickelung von Schollen noch wesentlich günstiger als in dem östlich dieser Linie gelegenen Abschnitt. Für die obigen Berechnungen kommt das nur deshalb nicht in Betracht, weil die Larvenmengen und die Zahl der laichreifen Tiere aus einer Summierung des Bestandes des ganzen Gebietes gewonnen sind. Wahrscheinlich geht man mit der Annahme nicht fehl, dass in dem westlichen Abschnitt dieses Gebietes alljährlich eine bestimmte Menge von Schollen die volle Entwickelung vom Ei bis zum Bodenstadium durchläuft und damit die Möglichkeit gegeben ist, dass ein gewisser Prozentsatz von jedem Jahrgang dauernd in diesem Meeresbecken gelebt hat".

Reibisch arrives at the conclusion that the bulk of the males in the true Baltic have immigrated from the Kattegat and the western Baltic, while he considers it probable that the bulk of the females are indigenous. As the males in the true Baltic according to Reibisch's opinion are several times as numerous as the females, he puts it forth as his opinion that far more than two thirds of the entire stock of plaice in the true Baltic have immigrated from the adjacent waters (pp. 199—200).

[1] Wissenschaftliche Meeresuntersuchungen. N. F. Bd. 13. Abt. Kiel 1911.

[2] Report IV of the Danish Biological Station 1894.

[3] Die Beteiligung Deutschlands an der internationalen Meeresforschung IV/V Jahresbericht. Berlin 1908 p. 139—140 & p. 143—144.

[4] A. C. Johansen: Contributions to the biology of the Plaice IV Medd. fra Komm. f. Havunders. Ser. Fiskeri Bd. III No. 5. 1908.

[5] Resultaten af den internationella Hafsforskningens Arbete under Åren 1907—1909. Stockholm 1910 p. 29—37.

While Petersen was of opinion[1] that it was mainly the quite young plaice of about 1 year which undertook the great migrations from the Kattegat or the Belt Sea to the Baltic[2], Reibisch believes it to be the older annual series from about 4 years of age and upwards which migrate into the true Baltic.

Dr. Reibisch's opinion concerning the stock of plaice in the Baltic is thus essentially in disagreement with the view which I have expressed in my treatise: "Is the plaice indigenous to the true Baltic"[3] and which tends to the following:

"The find of a numerous 0-Gr. of plaice in the true Baltic, both of bottom stages and pelagic stages, has invalidated the basis for the immigration hypothesis. From the moment when a considerable 0-Gr. is found to exist in the Baltic, we know nothing at all whether the number of the bottom stages of plaice immigrating to the Baltic is smaller or greater than that emigrating from the Baltic". (p. 13).

"A consideration of the size of the specimens of the same age in the Baltic, the Belt Sea and the southern Kattegat thus goes decidedly against the hypothesis that the majority of the specimens in the true Baltic should have immigrated either as 0-Gr. or as I-Gr. or as II-Gr. etc. There is, on the other hand, nothing to contradict the presumption that some specimens may have immigrated as 0-Gr. and some as I-Gr. etc.". (p. 17).

With regard to the transportation of the pelagic larvæ and the eggs, I have made the following remarks:

"The comparatively fresh surface water evidently carries several plaice larvæ out from the true Baltic to the Kattegat and the western Baltic, but in all probability more specimens are transported in the opposite direction by the salter water moving into the true Baltic. We may at any rate take it for granted that an exchange of specimens takes place between the true Baltic and the adjacent waters already while the plaice are in the pelagic stage. This exchange also takes place with regard to the older stages, but concerning these it is quite unknown whether the immigration to exceeds the emigration from the Baltic.

Of the plaice eggs which, as far as we know, can not float in water of less salinity than 10 ‰, more assuredly float into the true Baltic than out of it". (p. 9).

While Dr. Reibisch agrees with me concerning the transportation of the pelagic eggs and larvæ, he is of opinion that an immigration of the older annual series takes place on a large scale from the Kattegat and Belt Sea to the true Baltic, whereas the immigration in the opposite direction is insignificant in proportion to this.

Since I in 1908 put forward the view that we did not know any certain fact to serve as a basis for the supposition that the majority of the stock of plaice in the Baltic should have immigrated as bottom stages from other waters, there has — besides the paper of Prof. Reibisch — appeared another valuable German treatise, which is of importance for an investigation with regard to the renewal of the stock of plaice, viz. Prof. Apstein's paper: "Die Verbreitung der pelagischen Fischeier und Larven in der Beltsee und den angrenzenden Meeresteilen 1908—09"[4]. This treatise provides us with a provisional basis for a calculation as to the percentage of the plaice eggs which is destroyed before the larval stage is reached.

[1] That Dr. Petersen — according to the results of the recent investigations in the Baltic — has associated himself with the opinion that at any rate a part of the stock of plaice in the true Baltic is indigenous in these waters, appears from the following observations set forth in "Rapports et Procès-verbaux des Réunions" Vol. XI C. p. 37:

"Hr. Dr. Petersen sagt, dass er gern über den Stand der Untersuchungen in den verschiedenen Ländern benachrichtigt werden möchte. Dänischerseits könne er mitteilen, dass die Hauptbeschäftigung dieser Kommission [C 2] in dem vergangenen Jahre in den von Dr. Johansen in der Ostsee bis nach Bornholm ausgeführten Untersuchungen bestanden habe. Bei diesen Untersuchungen seien zahlreiche kleine pelagische Schollenlarven in der Ostsee und einige sogar bis östlich von Bornholm gefangen worden. Es sei also klar, dass die Scholle sich dort fortpflanze, eine Tatsache, von welcher er zum erstenmale durch diese Untersuchungen überzeugt worden sei. Kleine Bodenstadien seien nicht zahlreich aufgefunden, diese müssten dort aber gleichfalls vorkommen".

[2] Report IV of the Danish Biological Station. 1894; and Report XII of the Danish Biological Station 1905.

[3] Contributions to the biology of the Plaice IV. Medd. fra Kommissionen for Havundersøgelser, Ser. Fiskeri Bd. III, No. 5 1908.

[4] Wissenschaftliche Meeresunters. N. F. Abt. Kiel Bd. 13. 1911.

Besides the facts which have been set forth in the said papers by Reibisch and Apstein, we have also from the Danish investigations gained a series of experiences concerning the migrations of the young plaice towards the East in the Skagerak, and towards the South in the northern Kattegat[1], and with regard to the migrations of the marked plaice of later years in the Kattegat, the Belt Sea and the Baltic.

Therefore I have felt inclined to take up the whole question for renewed investigation, but as I have arrived at the same point of view as in 1908 I feel obliged to combat a series of the conclusions drawn by Prof. Reibisch in his aforesaid paper.

Dr. Reibisch's arguments to prove that only a smaller part of the stock of plaice in the Baltic is indigenous to this sea are falling into two great divisions:

1) A group of arguments to show that immigration on a large scale takes place: a) from the Kattegat to the western Baltic and further to the true Baltic b) from the Kattegat through the Sound to the true Baltic.
2) A calculation to show that the number of larvæ which the present author calculated for the Baltic in 1908, would not have been sufficient for the renewal of the stock of plaice.

II. Dr. Reibisch's age determinations of the plaice.

It is well known and generally appreciated that Prof. Reibisch through the study of the otoliths of the plaice has obtained results of great importance for the rational investigations of the stock of fish in the sea. From this fact it does not follow, however, that we are able to employ the otoliths for exact and reliable age determinations approximately to the degree supposed by Reibisch.

Heincke[2] as well as the present author[3] have previously emphasized that the otoliths of the older annual series of plaice are as a rule not fit for exact age determinations, and especially not those of the Baltic plaice. Prof. Reibisch has however paid no heed to the experience gained in that respect, he has on the contrary indicated the probable exact age for every one of the old plaice he has had in hand. He believes that even for the old plaice the age can be determined with greater certainty by means of the otoliths than by means of the bones, while Heincke has arrived at the opposite result. It is also evident that Reibisch and Heincke determine the age of the old plaice in the Baltic quite differently.

We find an indication of this in an expression by Franz, who remarks on the basis of Prof. Heinckes investigations concerning the age of the Baltic plaice; that "Reibisch's Altersbestimmungen der grösseren Ostseeschollen sicher grösstenteils falsch sind"[4]. This remark refers surely to earlier investigations by Reibisch, but considering that he still employs his old method for the age determination, and seeing that he has never found a male plaice in the Baltic to which he attributes a greater age than 13 years, and never a female plaice to which he attributes a greater age than 17 years, it will be evident that Heincke ascribes a much greater age to the old Baltic plaice than Reibisch does.

[1] A. C. Johansen: Bericht über die dänischen Untersuchungen über die Schollenfischerei etc. Medd. fra Komm. for Havundersøg. Ser. Fiskeri Bd. III, Nr. 8 1910.

[2] Die Beteiligung Deutschlands an der internationalen Meeresforschung IV Jahresbericht. Berlin 1908. p. 95—96.

[3] A. C. Johansen: "Ueber die Schollenfischerei im Kattegat und die Mittel, sie zu heben". p. 89. Rapports et Procès-verbaux. Conseil perm. intern. Vol. V. 1906.

[4] Viktor Franz: "Die Eiproduktion der Scholle". Wissensch. Meeresunters. N. F. IX Bd. Abt. Helgoland 1908 p. 113.

My experience with regard to the fitness of the otoliths and the opercular bones for the determination of the age of old specimens is, that the inner annual rings may as a rule be distinguished most plainly in the otoliths and the outer ones in the opercular bones. In this respect I am quite of Heincke's opinion. In old plaice where the otoliths have thick edges, frequently in position at about right angles to the upper plane of the otoliths, they cannot as a rule even be used for an approximate determination of age. Here we can on the contrary very often use the opercular bones — and especially the *interperculare* — for approximate age determinations. Where the question is about males of the Baltic plaice above an age of 3 years, we must in very many cases give up the thought of exact age determination, even if we use the otoliths as well as the opercular bones. Owing to their far quicker growth we can for the females as a rule make good age determinations, even for considerably older series.

A reason why I regard Reibisch's age determinations of the male plaice from the western and the true Baltic with scepticism, even in the cases where he regards what he calls normal otoliths, is, that we can not in Reibisch's material respecting the males trace any similar movement in the relative frequency of specimens of the different annual series as in the case of the females.

Fig. 1. The division of the Baltic. According to Reibisch.

I have in an earlier paper pointed out that the year 1904 was a very unfavourable one for the development of the plaice fry in the true Baltic, the Belts and the southern and middle Kattegat[1]. Neither was the year 1905 very favourable for the development of the fry in certain parts of these waters, and especially not in the true Baltic. 1903 and 1906 were, on the other hand, far better years in the said respect. If we now consider the result of Reibisch's determinations of age, the proportionately slight number of females from 1904 and partly from 1905 quite confirm the result of my investigations, while with regard to the males it can not be traced that proportionately few specimens were developed in any of these years. Reibisch represents the result of his investigations of the age of the plaice in the following way (pp. 159—162).

[1] Contributions to the biology of the Plaice III. Meddelelser fra Komm. for Havunders. Ser. Fiskeri Bd. III 1908.

Region I [1] Males.

Annual series.

	08	07	06	05	04	03	02	01	00	99	98
Number with sloping otoliths						21	48	32	17	6	2	2
— — normal —		1	2	33	83	109	96	47	25	7	5	
Total number	1	2	33	83	130	144	79	42	13	7	2	

Region I Females.

Annual series.

	06	05	04	03	02	01	00	99	98	97	96	95
All with normal otoliths	21	51	38	62	39	23	5	7	—	—	1	1

Region II Males.

Annual series.

	07	06	05	04	03	02	01	00	99	98	97	96
Number with sloping otoliths		1	3	18	35	41	30	14	10	4	3	1
— — normal —	6	21	44	41	27	18	4	4	1	—	—	—
Total number	6	22	47	59	62	59	34	18	11	4	3	1

Region II Females.

Annual series.

	07	06	05	04	03	02	01	00	99	98	97	96	95	94	93
Number with sloping otoliths								1	2	3	—	1	1	—	1
— — normal —	4	26	30	26	50	30	17	17	9	5	4	2	2	2	1
Total number	4	26	30	26	50	30	17	18	11	8	4	3	3	2	2

Region III Males.

Annual series.

	07	06	05	04	03	02	01	00	99	98	97	96
Number with sloping otoliths		1	15	55	145	145	114	55	32	14	3	2
— — normal —	8	75	84	85	65	28	11	2	—	1	—	—
Total number	8	76	99	140	210	173	125	57	32	15	3	2

Region III Females.

Annual series.

	08	07	06	05	04	03	02	01	00	99	98	97	96	95	94	93
Number with sloping otoliths						1	5	3	3	7	3	4	—	—	—	1
— — normal —	1	1	72	93	73	117	49	40	15	13	9	6	2	1	1	2
Total number	1	1	72	93	73	118	54	43	18	20	12	10	2	1	1	3

Region IV Males.

Annual series.

	07	06	05	04	03	02	01	00	99	98	97
Number with sloping otoliths	1	5	27	65	62	61	43	18	10	1	
— — normal —	1	11	17	36	27	10	4	3	—	—	—
Total number	1	12	22	63	92	72	65	46	18	10	1

Region IV Females

Annual series.

	07	06	05	04	03	02	01	00	99	98	97	96	95
Number with sloping otoliths							4	2	3	2	2	1	1
— — normal —	2	26	9	12	50	24	17	6	13	2	2	4	—
Total number	2	26	9	12	50	24	21	8	16	4	4	5	1

From these figures it will be seen that proportionately only few females are present from the series 1904 and partly from 1905, while there is no sign that the number of males is also small in any of these years.

[1] Concerning the limits of the various Regions see Fig. 1 p. 6.

I explain this in the following way:

Owing to the quicker growth of the females, the age determinations are in their case far more reliable than for the males. The age determinations are for males only approximate determinations, and when we for instance see that proportionately many more males than females are referred to the annual series 1904, it is owing to inaccurate age determinations for the males, as several specimens from other annual series have been put down as belonging to the series 1904. If we look for any other explanation of this difference in the individual richness of each of the two sexes, we must either suppose a very great immigration of males to have taken place in the western and true Baltic from other waters, or that the males in the years which are proportionately unfavourable for the appearance of the fry, have predominated to a greater extent than normally over the females.

A great immigration from other waters of the males is most improbable. From our numerous marking experiments in the Kattegat we can not quote any example of migrations from the Kattegat to the Baltic (See Chap. III). Moreover our marking experiments in the Belt Sea and the Baltic point in the direction — as is mentioned in Chap. III — that the males in these waters do not undertake more extensive migrations than the females.

That the females should constitute a far higher percentage than normally of the hatched individuals in the years unfavourable to the forthcoming of the fry is à priori improbable, and the available observations indicate decidedly that this is not the case. Franz[1] has in his investigations concerning the percentage of specimens of each of the two sexes of the 0 group of the plaice in the western Baltic arrived at the following figures[2].

	Number		Percentage	
	males	females	males	females
1903	251	188	57·18	42·82
1904	41	71	36·61	63·39
1905	34	30	53·12	46·88
1906	122	113	51·91	48·09

These figures do not suggest — as will be seen — that the males of the annual series 1904 predominated unusually over the females. The number of females from 1904 is moreover greater than the number of males, still it must not be forgotten that we have here only dealt with a rather slight number of individuals.

My investigations concerning the number of individuals of each of the two sexes of the I-group in the true Baltic, point also in the direction that in the annual series from 1905[3] and 1906 the proportion between the number of males and females was about the same, 56·6 % of males and 43·4 of females occurring of the former series, and 53·2 % of males and 46·8 % of females of the latter series[4]. (See Table 1).

In this connection it should also be remembered that in the Baltic, where the conditions for the hatching of eggs must be supposed to be far less favourable than in the North Sea, an equally large percentage of females is hatched as in the North Sea[5].

From what has been stated here, it will be seen that I regard Dr. Reibisch's age determinations of males of the Baltic plaice with scepticism. Concerning the individuals of which the otoliths are described as normal by Prof. Reibisch, I believe that the determinations — in spite of all pains taken

[1] Viktor Franz: Die Eiproduktion der Scholle. Wissensch. Meeresunters. N. F. IX Bd. Abt. Helgoland 1908.

[2] I have only taken the figures into consideration which refer to determinations of sex, which Franz regards as perfectly safe.

[3] The year 1905 was, as mentioned above, an unfavourable year for the development of the plaice fry in the true Baltic.

[4] The small size of the individuals of the I group in the true Baltic suggests that they have grown up in these waters; this is also supposed by Reibisch. (Comp. A. C. Johansen: Contributions to the biology of the Plaice IV).

[5] Comp. Viktor Franz: Die Eiproduktion der Scholle. Wissensch. Meeresunters. N. F. IX Bd. Abt. Helgoland 1908.

Table 1. Showing the size and the percentage of males and females of Plaice of the I-Group captured in the Danish fishing experiments in the true Baltic in 1905—07.

Date	Station No.	Locality	Depth meters	Fishing Apparatus	Year hatched	Number ♂	Number ♀	Number ?	Percentage ♂	Percentage ♀	Sex	Size cm 4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1905 Nov. 16	707	E of Falster 54°49′N 12°18′E	22	50 f. Ottertrawl	1904	.	1	.	.	100	♂																	
											♀								1									
» » 16	708	S of Møen 54°54′N 12°26′E	21	—	—	1	1	.	50·0	50·0	♂								1									
											♀								1									
1906 Sept. Oct.		SW Coast of Bornholm, Rønne			1905	25	24	.	51·0	49·0	♂				1	2	6	3	8	2	3						
											♀				1	1	.	1	4	11	3	2	1				
1907 March 13	885	N of Darsserort 54°39′N 12°29′E	17	50 f. Ottertrawl	—	50	33	.	60·2	39·8	♂					3	13	11	12	6	5	.					
											♀					2	7	6	8	7	2	1					
» » 24	906	E of Gedser 55°35′N 12°12′E	17	—	—	42	28	.	60·0	40·0	♂				2	7	4	15	7	4	2	1					
											♀				2	6	7	3	3	5	.	.	1	1			
» » 24	908	Off Zingst 54°32′N 12°45′E	14	—	—	5	5	.	50·0	50·0	♂							1	1	1	1	.	.	1				
											♀								3	1	.	.	.	.	.	.	.	1
» » 25	911	E of Rügen 54°32′N 14°04′E	17	—	—	2	2	.	50.0	50·0	♂						1	.	.	1	.	.	.	.	.	.	.	
											♀					1	.	1	.	.	.	.	.	.	.	.	.	
» » 25	912	NE of Rügen 54°52′N 13°44′E	47	—	—	1	.	.	100	.	♂											1						
											♀																	
» » 26	915	S of Møen 54°52′N 12°25′E	17	—	—	13	14	.	48·1	51·9	♂					1	2	4	4	.	.	2	.	.	.	.	.	
											♀					1	4	3	5	1	.	.	.	.	.	.	.	
» July 17	1120	E of Falster 54°37′N 12°25′E	15	Young Fish Trawl	1906	31	20	.	60·8	39·2	♂		1	5	19	5	1	.	.	.	.	.	.	.	.	.	.	
											♀			2	15	3	.	.	.	.	.	.	.	.	.	.	.	
» » 23	1126	E of Rügen 54°20′N 14°04′E	15	—	—	6	10	.	37·5	62·5	♂					.	.	1	5	.	.	.	.	.	.	.	.	
											♀				1	2	1	3	3	.	.	.	.	.	.	.	.	
» » 23	1127	Oder Bank 54°21′N 14°56′E	14	—	—	1	1	.	50·0	50·0	♂		1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
											♀				1	.	.	.	.	.	.	.	.	.	.	.	.	
» » 27	1146	Sandvig Bay, Bornholm	2	Young Plaice Trawl	—	.	.	1	.	.	?		1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	
» » 29	1147	SE of Rønne, Bornholm	1—4	—	—	.	.	3	.	.	?			3	.	.	.	.	.	.	.	.	.	.	.	.	.	
» » 31	1151	E of Rügen 54°30′N 13°50′E	16	Young Fish Trawl	—	.	2	1	.	.	?				.	.	.	.	1	.	.	.	.	.	.	.	.	
											♀				.	.	1	.	1	.	.	.	.	.	.	.	.	
» August 1	1152	NE of Rügen 54°38′N 13°49′E	24	—	—	12	12	.	50·0	50·0	♂				2	4	1	3	2	.	.	.	.	.	.	.	.	
											♀				.	4	4	3	1	.	.	.	.	.	.	.	.	
» » 2	1154	S of Møen 54°52′N 12°25′E	17	50 f. Ottertrawl	—	23	22	.	51·1	48·9	♂				.	12	10	1	.	.	.	.	.	.	.	.	.	
											♀				1	9	11	1	.	.	.	.	.	.	.	.	.	
» » 2	1155	Rytsebæk, S Coast of Møen	1—4	Young Plaice Trawl	—	.	.	1	.	.	?				.	.	.	.	1	.	.	.	.	.	.	.	.	
» » 3	1157	N of Darsserort 54°39′N 12°29′E	17	Young Fish Trawl	—	8	6	.	57·1	42·9	♂				.	2	4	1	1	.	.	.	.	.	.	.	.	
											♀				.	3	.	2	1	.	.	.	.	.	.	.	.	
» » 3	1160	Plantagenet Gr. 54°39′N 12°48′E	8	—	—	1	1	.	50·0	50·0	♂							1	.	.	.	.	.	.	.	.	.	
											♀						1	.	.	.	.	.	.	.	.	.	.	
» » 3	1162	SE of Møen 54°50′N 12°48′E	21	—	—	40	42	.	48.8	51·2	♂			1	2	19	17	1	.	.	.	.	.	.	.	.	.	
											♀				2	18	20	2	.	.	.	.	.	.	.	.	.	
» » 3—4	1163	SE of Møen 54°49′N 12°47′E	19	—	—	38	25	.	60·3	39·7	♂				3	13	20	2	.	.	.	.	.	.	.	.	.	
											♀				3	9	11	2	.	.	.	.	.	.	.	.	.	

— can only be regarded as approximate determinations, where one or a few years may differ in many cases. For the specimens having sloping (abgeschrägten) otoliths I consider the determinations far more uncertain; probably they are frequently wrong in respect of many years[1].

Now Prof. Reibisch's age determinations play a rôle in his discussion as to how far a greater or lesser part of the stock of plaice in the true Baltic is indigenous to these waters. On the basis of his age determinations Reibisch supposes a very great annual waste to take place in the stock of the grown-up plaice, a waste namely of 50 %. However, when we regard it as probable that Reibisch has stated a too early age for many of the specimens of his material, we may naturally reckon with a lesser waste. The bearings of this will be discussed in a later section (IV).

III. Dr. Reibisch's evidence to show a migration of plaice from the Kattegat and Belt Sea to the true Baltic.

A. The supposed migrations of the plaice from the Kattegat through the Belt to the western Baltic and from the western Baltic to the true Baltic.

By an investigation of the otoliths of the plaice in the western and true Baltic, Reibisch has arrived at the conclusion that the shape and structure of the otoliths may enable us to see if the fish has grown up in the area where it occurs, or if it has immigrated from other places where the life conditions are more favourable.

Dr. Reibisch here divides the otoliths into two groups: — Firstly the normal otoliths which are not essentially thickened and in which all the annual rings from the centre to the edge can be seen plainly. — Secondly the sloping (abgeschrägten) otoliths, which are strongly thickened and in which the annual rings, so to speak, disappear at the foremost edges of the otoliths.

Reibisch now takes it for granted that the first type of otoliths appears only in plaice which continuously keep inside an area with somewhat homogeneous life conditions, while the other type only occurs when the plaice immigrates to areas where the life conditions are less favourable than where they lived previously.

Through investigations of the otoliths in the four areas of the western and true Baltic, which are sketched on the chart Fig. 1, Reibisch has found that the percentage of plaice with "sloping" otoliths is largely increasing in an eastern direction from I towards IV. The figures which Dr. Reibisch has found stating the percentage of specimens with sloping otoliths are as follows:

In region	I	II	III	IV
For males	25·6	53·4	67·8	75·1
For females	0·0	4·4	6·0	9·7

Reibisch now explains the occurrence of these sloping otoliths and the increase in number in the following way:

The specimens with sloping otoliths in region I have immigrated from the Kattegat and have come into region I either through the Little Belt or through the Great Belt.

[1] On the whole it is my opinion that we in a higher degree than most naturalists have realized hitherto, must reckon with the fact that age determinations undertaken by means of otoliths, opercular bones, or scales etc. are very frequently not quite exact age determinations, but only approximate determinations.

The specimens with sloping otoliths in region II have partly come from region I, partly from the Kattegat through the Great Belt.

The specimens with sloping otoliths in region III have come from region II.

The specimens with sloping otoliths in region IV have partly come from region III, partly from the Kattegat through the Sound.

The fact that we find an increase in the percentage of sloping otoliths from west towards east must thus, according to Reibisch, signify that plaice in great numbers migrate from west towards east, and the fact that many more males than females have sloping otoliths furnishes us, according to Reibisch, with a proof that the males are far more inclined to undertake long migrations than the females.

To this I will make the following comments:

Reibisch is right when he says that from the period where the increase in length begins to be slow the otoliths grow proportionately little in length but proportionately much in thickness. In the very slowly growing plaice the lime deposition takes place predominantly on the basal part of the otoliths, that means on the side adjacent to the nerve. Sloping otoliths may thus undoubtedly appear in the way supposed by Reibisch: that the plaice migrates from areas with proportionately favourable life conditions to areas with proportionately bad life conditions. Still there is not the slightest reason to suppose that the sloping otoliths can only appear in this way. The qualification needed for the appearance of sloping otoliths is that the growth of the plaice reaches a certain minimum; there is however every possible reason to suppose that this minimum must be reached once, when the plaice continually lives inside the same area where the life conditions are proportionately unfavourable. (This may perhaps even be reached by very old plaice in areas where the life conditions are most favourable).

Reibisch maintains certainly that the sloping of the otoliths commences quite suddenly at one particular annual ring, but my experience has not confirmed this. It has on the contrary generally not been possible for me to indicate precisely at which annual ring the "sloping" commences. The notion "sloping otoliths" cannot on the whole be defined nearly so precisely and exactly as Dr. Reibisch seems to think. A remark of Reibisch's also indicates a certain want of definiteness in the distinction between "normal" and "sloping" otoliths. He writes as follows p. 136.

"Wo eine typische Abschrägung vorliegt, ist dies durch Angabe des Ringes, bei dem sie beginnt, bemerkt. Auch hier handelt es sich um eine Schätzung[1], die sich darnach richtete, ob und bei welchem Ringe an der Hinterkante des Otolithen der blinden Seite die oben beschriebenen Wülste sichtbar wurden[2], in Verbindung mit dem Verschwinden einer erkennbaren Schichtung an der vorderen Kante beider Otolithen".

When we frequently notice that from a certain point the rings have become considerably narrower than those of an earlier formation, we possess here as a rule a means for the determination of the age at which the plaice became mature, as the rapidity in growth decreases considerably from the time of maturity, but it is often the case that the annual rings are plain and distinct also after maturity, even if they are narrow.

The fact that the percentage of the sloping otoliths is increasing towards east in the western Baltic I do not explain as Reibisch does, by supposing that the plaice on a large scale migrate towards east, but simply by the fact that the life conditions for the plaice become less and less favourable in the Baltic the further we get towards the east. The salinity decreases, the fauna becomes poorer, the

[1] Italicized by the present author.

[2] Reibisch writes about these "Wülste" on p. 136: "An den abgeschrägten Otolithenkanten ist bei starker Aufhellung überhaupt keine Schichtung sichtbar, während in der Kochsalzlösung eine eigentümliche optische Erscheinung auftritt. Bei richtiger Beleuchtung macht es den Eindruck, als trüge die schräge Kante eine Anzahl parallel verlaufender Wülste, die, wie der Schliff zeigt, ja tatsächlich nicht vorhanden sind, die vielmehr durch die verschiedene Lichtbrechung von je 2 aufeinanderfolgenden Halbjahrsringen vorgetäuscht werden".

salt water animals, and among these the plaice, become gradually smaller as we move towards the east. So it is quite natural that the otoliths of the plaice also to a higher degree must bear the impress of the dwarf nature in the eastern than in the western parts of the Baltic.

Should Dr. Reibisch's explanation concerning the origin of the sloping otoliths be right, it would imply, as Reibisch himself observes, that the males undertake far more extensive migrations than the females. It is namely the quite predominant number of the males in the regions III and IV which have sloping otoliths and which consequently, according to Reibisch's theories, have immigrated from other areas, while only quite a low percentage of the females have sloping otoliths even in these regions (See p. 10).

The Danish marking experiments in the true Baltic, the western Baltic and the Great Belt suggest however that the males in these waters do not undertake more extensive migrations than the females. There is no essential difference as to the extent of the migrations of the individuals of the two sexes.

The Danish marking experiments with plaice in the Belt Sea and the Baltic are illustrated on Fig. 2—4. From these figures we get an immediate impression that Reibisch's hypothesis that the males wander much further than the females in the Belt Sea and adjacent parts of the true Baltic, is quite wrong.

The results of the Danish marking experiments in the above mentioned waters are represented in detail in Table 5, of which the tables below 2—3 and 4 are extracts. In the tables the distance between the place of recapture and place of liberation has been stated for each of the recaptured specimens of each sex for each month.

Table 2.

Experiment with marked plaice 10 miles N. 1/2 E. of Darsserort (54° 39' N. 12° 29' E.) 17 Meters. March 13 1907.

No of months between liberation and recapture	Distance (miles) between place of recapture and place of liberation, (every figure corresponds to one Individual plaice).	
	Males	Females
2	9, 11	
3	5, 7, 9	6, 7
4	3, 5	11
5		82
6	8 1/2	2, 11
7	2, 5, 7, 9	
8	11	
11	38	
14	17, 48	
15	2	
16	8, 11	
17	7	
19	33	
26	13, 13	
28	34	
31	2	45
38		15
39	13	
41		15
42	5	
48	39	39
50	13	

If we regard Table 2 which illustrates a marking experiment from the boundary area between the western Baltic and the true Baltic, it will be seen that between the 2nd and 6th month after liberation 8 males and 6 females were recovered for which the place of liberation is known, the average distance

between the place of recovery and liberation is for the males 7·2 miles and for the females 19·8 miles. The great predominance of the latter figure is due, however, to one single fish.

From the 7th to the 28th month males alone were recaptured, a total of 16 specimens, and the average distance between the place of recapture and liberation was in their case 16·1 miles.

From the 31st to the 50th month 5 males and 4 females were recaptured. The males had on an average wandered 14·4 miles from the place of liberation, the females on an average 28·5 miles.

Table 3 illustrates the migrations of the two sexes in a marking experiment in the western Baltic. This table shows that from the 1st to the 5th month after liberation 11 males and 5 females were recaptured with places of recapture known. The average distance between the place of recapture and liberation was for the males 6·8 miles, for the females 9·7 miles. If we look away from the recaptures in the first month after liberation, we find the average distance between the place of recapture and liberation for 4 males to be 13·5 miles and for 4 females 11·5 miles.

Between the 12th and 36th month after liberation 7 males and 4 females were recovered. The average distance from the place of liberation was for the males 6·5 miles, for the females 8 miles.

Table 4 shows the extent of the migrations of the two sexes in a marking experiment in the Great Belt. In the 1st and 2nd month after liberation 5 males and 12 females were recaptured, with the places of recapture known. The average distance from the place of liberation was for the males 2·1 miles for the females 3·7 miles. From the 3rd to the 15th month after liberation 16 females were recovered, which on an average had wandered 12·4 miles. In the 16th month after liberation one male and one female were recovered, each of them had removed 14 miles, and in the 25th and 26th month 3 females were recovered at an average distance of 14·2 miles from the place of liberation.

Table 3.

Experiment with marked plaice 4 miles WSW. of Bagenkop harbour, Langeland (54° 43′ N. 10° 35′ E.). 25 Meters. March 15 1907.

No of months between liberation and recapture	Distance (miles) between place of recapture and place of liberation. (Every figure corresponds to one Individual plaice).	
	Males	Females
1	2½, 2½, 3, 3, 3, 3, 3½	2½
2	4, 27	7, 14
3		18
4	15	
5	8	7
12	3, 3½	3
13		6
15	8½	
19	19	
25	3, 4, 4½	
35		20
36		3

Table 4.

Experiment with marked plaice at the entrance to the Bay of Kerteminde, Great Belt, (55° 25′ N. 10° 46′ E.). 17 Meters. March 18 1907.

No of months between liberation and recapture	Distance (miles) between place of recapture and place of liberation. (Every figure corresponds to one Individual plaice).	
	Males	Females
1	4½	2, 3½, 4½
2	1, 1, 2, 2	1, 1, 1, 1, 2, 2½, 2½, 7, 16
3		1, 16
4		12, 13, 15, 18, 24
5		4½, 11, 13, 13, 28
12		11
13		1
14		11
15		7
16	14	14
25		2
26		8½, 32

The figures of the Tables 2—4 as well as the charts Fig. 2—4 plainly point in the direction that the males in the Belts and in the western Baltic do not undertake more extensive migrations than the females, which would of necessity be the case if Reibisch's hypothesis of the migrations as a reason for the appearance of the "sloping" otoliths were right. The positive observations speak here quite another language than Dr. Reibisch's hypothesis.

Dr. Reibisch sets forth another point which according to his notion favours the idea that a migration of plaice takes place from the Kattegat through the Little Belt to the western Baltic.

In the western part of the Baltic we usually find a number of plaice whose otoliths, by indicating a rapid growth, deviate from the normal type in this area. About this Reibisch writes as follows (p. 144).

"Eine direkte Einwanderung von Schollen aus dem Kattegatt in die Ostsee kann durch die Belte und den Sund erfolgen, und zwar zunächst nach den Regionen I, II und IV. Untersucht man Fänge aus Region I, so findet man sehr regelmässig eine Anzahl Tiere mit ganz dünnen Otolithen, die ausserdem, verglichen mit der Mehrzahl etwa gleich grosser Individuen aus demselben Gebiet, sehr breite Schichten für den 2. und 3. Jahrgang besitzen, und um ein oder mehrere Jahre jünger sind als letztere. Diese Formen sind jedenfalls in der Hauptsache als Kattegatt-Schollen, die durch den kleinen Belt eingewandert sind, in Anspruch zu nehmen".

Fig. 2. A Danish marking experiment with plaice in the true Baltic. March 13 1907. — Only males represented here.

To this I will make the following remarks:

It is true that we in the western part of the Baltic find several specimens whose otoliths show that they have had a rapid growth[1]. But I find no reason to suppose that these specimens have immigrated from the Kattegat. They might very well have come from the Little Belt, where the water is of a higher salinity and where the rapidity in growth on an average is greater than in the western Baltic. It is, however, also possible that the greater part of these rapidly growing specimens originate from the very shore waters of the western part of the western Baltic, from the water south of Funen and from the east coast of Slesvig etc.

[1] Reibisch l. c. Table 3 and the author's age-analysis in: "Om Rødspætten og Rødspættefiskeriet i Beltfarvandet", København 1912. Tabel 12—13.

The specimens which remain proportionately long in these nutritive shore waters, grow probably more rapidly than the specimens which earlier migrate out into deeper water in the western Baltic.

There is no reason to suppose that the proportionately quickly growing specimens originate from the waters around Samsø (which Reibisch reckons as belonging to the Kattegat) as the plaice in these waters does not grow more rapidly than in the boundary area between the western Baltic and the Little Belt[1].

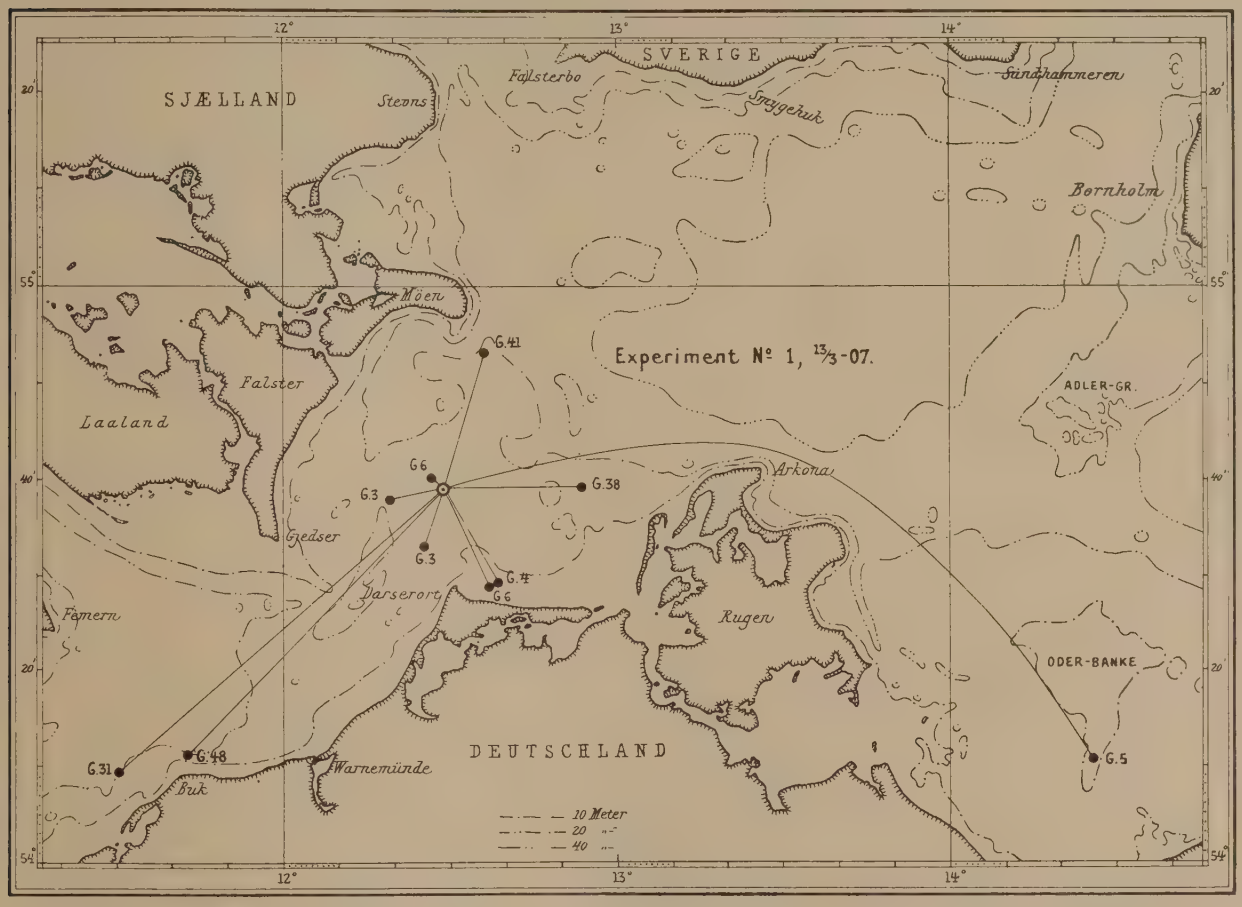

Fig. 3. A Danish marking experiment with plaice in the true Baltic. March 13 1907. — Only females represented here.

Of the greatest importance in this connection it is, however, that in the numerous marking experiments with plaice in the Kattegat, from which more than 2000 specimens have been recovered, we have never had the experience that a plaice liberated in the Kattegat later on has been recaptured in the Little Belt.

It is naturally very possible that one or other specimen may wander from the Kattegat through the Little Belt to the western Baltic, but the marking experiments plainly show that we have not here to do with regular migrations on a large scale[2].

[1] A. C. Johansen: "Om Rødspætten og Rødspættefiskeriet i Beltfarvandet" etc. København 1912.

[2] A. C. Johansen: Contributions to the biology of the Plaice II. Medd. Komm. f. Havunders. Ser. Fiskeri, Bd. II, No. 5 1907. — l. c. 1912.

Fig. 4. Two Danish marking experiments with plaice in the Belt Sea. March 1907.
The arrow heads represent males, the dark circles females.

Prof. Reibisch has found by his investigations that the female plaice from the 3rd annual series and the male plaice of the 6th annual series and upwards are not smaller in the true Baltic than in the eastern part of the western Baltic (Region III Fig. 1) but rather a little larger. In this case there is from a theoretical point of view nothing to contradict the presumption that a part of the stock of older specimens in region IV might have immigrated from region III. But we have still no proofs that the migration of bottom stages from region III to region IV takes place to a greater extent than the migrations in the opposite direction. Heincke, when mentioning the German marking experiments with plaice and flounder in the western Baltic, writes as follows[1]: (p. 143).

"Über die Richtung und Ausdehnung der Wanderungen der Schollen in der Ostsee ist noch besonders hervorzuheben, dass uns keine Tatsachen bekannt geworden sind, die für eine Wanderung von Westen nach Osten sprechen und dahin gedeutet werden könnten, dass grössere Schollen von etwa 15 cm an regelmässig und in grössere Zahl aus der westlichen in die östliche Ostsee hinüber ziehen und den Bestand derselben vergrössern oder ergänzen. Die Wiederfangorte der markierten Schollen liegen vielmehr fast ausnahmlos in derselben geographischen Längenzone, wie die Aussetzungsstellen. Dass überhaupt wohl keine weiten Wanderungen stattfinden, geht u. a. auch noch daraus hervor, das markierte Schollen und Flundern, die im zweiten Jahre nach dem Aussetzen wiedergefangen wurden, durchweg in denselben Gegenden angetroffen wurden, wie solche, die schon im ersten Jahre wieder ins Netz gerieten".

A Danish marking experiment in the western part of the true Baltic suggests that some few plaice undertake rather long migrations in these regions (See Fig. 2—3). But the Danish experiments have in the main confirmed Prof. Heincke's before mentioned statements[2].

Table 5. Showing particulars of liberation and recapture of plaice in the ordinary Danish marking experiments in the Belt Sea and the Baltic in March 1907.

Particulars of Liberation. Date. Locality. No of fish. etc.	Particulars of Recovery												Remarks
	Date		No on Label	Locality reported	Central Position (Approximately) N.	Central Position (Approximately) E.	Distance between Place of Recapture and Place of Liberation, miles	Nationality of fishing vessel	No of months between Liberation and Recovery	Sex	Initial Size cm	Ultimate Size cm	
1907 March 13	1907	May 26	3269	8 miles S of Møen [Light]	54°49′	12°35′	11	German	II	♂	22·5	22·5	
10 miles N½E	»	» 27	3392	4 miles NW of Darsserort	54°30′	12°25′	9	»	II	♂	21·5	22·0	
of Darsserort	»	June 15	3290	6 miles NNW of Darsserort	54°33′	12°25′	7	»	III	♀	25·0	25·5	
54°39′ N	»	» 20	3334	5 miles NW of Darsserort	54°31′	12°23′	9	»	III	♂	23·0	23·5	
12°29′ E	»	» 27	3225	12 miles NNW of Darsserort	54°38′	12°19′	6	»	III	♀	24·0	24·0	
17 meters	»	» 27	3273	18 miles N of Darsserort	54°46′	12°25′	7	»	III	♂	20·5	20·0	
"Thor"	»	» 28	3213	6 miles N of Darsserort	54°34′	12°29′	5	»	III	♂	21·5	.	
St. 885	»	July 1	3250	8 miles N of Darsserort	54°36′	12°28′	3	»	IV	♂	20·0	20·5	
200 mature	»	» 1	3314	6 miles N of Darsserort	54°34′	12°29′	5	»	IV	♂	23·0	23·0	
Plaice liberated	»	» 28	3341	4 miles E of Darsserort	54°29′	12°38′	11	»	IV	♀	22·0	.	
(No 3201-3400)	»	August 28	3274	South-End of Oderbank	54°10′	14°26′	82	»	V	♀	21·5	22·0	
"Thor"s	»	Sept. 7	3380	12 miles N of Darsserort	54°40′	12°27′	2	»	VI	♀	23·0	.	
marking	»	» 14	3218	c. 4 miles E of Darsserort	54°29′	12°38′	11	»	VI	♀	22·0	23·0	
experiment	»	» 14	3304	3 miles NE of Darsserort	54°31′	12°34′	9	»	VI	♂	20·5	20·5	
No 1 1907	»	Octbr. 12	3329	c. 2 miles NNE of Darsserort	54°30′	12°31′	9	»	VII	♂	21·0	21·5	

[1] Die Beteiligung Deutschlands an der internationalen Meeresforschung IV/V Jahresbericht, Berlin 1908.

[2] That the very form or configuration of the sea bed — as supposed by Reibisch — should cause the older plaice of show a more marked inclination to migrate from the western Baltic to the true Baltic than in the opposite direction has always been incomprehensible to me. I could imagine that the older plaice might show such an inclination if the depth was constantly increasing in an eastern direction in the western Baltic and further into the true Baltic to the Bornholm Deep. The fact is however, that the depth in the western Baltic rather increases in a western direction from the Gedser-Darsser Ridge to the entrance of the Little Belt (See Fig. 5).

Table 5. Continued.

Particulars of Liberation. Date. Locality, No of fish. etc.	Particulars of Recovery: Date	No on Label	Locality reported	Central Position (Approximately) N	E	Distance between Place of Recapture and Place of Liberation, miles	Nationality of fishing vessel	No of months between Liberation and Recovery	Sex	Initial Size cm	Ultimate Size cm	Remarks
	1907 Octbr. 12	3398	8 miles NNW of Darsserort	54°35′	12°23′	5	German	VII	♂	20·5	21·5	
	» » 15	3367	6 miles NE of Darsserort	54°33′	12°36′	7	»	VII	♂	21·0	21·5	
	» » 30	3230	10 miles N of Darsserort	54°38′	12°27′	2	»	VII	♂	21·0	21·5	
	» Nov. 22	3325	4 miles E of Darsserort	54°29′	12°38′	11	»	VIII	♂	20·5	20·0	
	1908 Febr. 20	3298	Between Heiligenhafen & Warnemünde	54°18′	11°35′	38	»	XI	♂	21·5	21·0	
	» May 21	3204	Off Smygehuk 32 m	55°16′	13°22′	48	Swedish	XIV	♂	22·0	24·5	
	» » 26	3378	12 miles NNW of Dornbusch Light	54°46′	12°56′	17	German	XIV	♂	21·5	21.5	
	» June 21	3291	10 miles N of Darsserort	54°38′	12°27′	2	»	XV	♂	20·0	21·0	
	» July 1	3238	5 miles NE of Darsserort	54°32′	12°36′	8	»	XVI	♂	23·0	.	
	» » 15	3264	Plantagenet Ground	54°39′	12°47′	11	»	XVI	♂	21·5	.	
	» August 20	3356	4 miles N of Darsserort	54°32′	12°29′	7	»	XVII	♂	21·5	21·5	somew. dry
	» Octbr. 3	3276	Between Heiligendamm and Warnemünde	54°12′	11°56′	33	»	XIX	♂	21.5	21·0	
	1909 May 11	3232	c. 10 miles WNW of Hiddensoe Lighthouse	54°38′	12°51′	13	»	XXVI	♂	20·0	21·5*	Tail damaged * 17·5 without tail
	» » 21	3310	c. 8 miles SSW of Møen Isl.	54°50′	12°40′	13	»	XXVI	♂	21·0	21·0	
	» July 5	3223	Between Warnemünde and Wismar, off Buk-Lighthouse, within Sight of the Danish coast	54°22′	11°39′	34	»	XXVIII	♂	21·0	21·5*	* 17·7 without tail
	» Octbr. 20	3244	Off Alt Gaarz. 4 miles from shore	54°09′	11°31′	45	»	XXXI	♂♀	20·5	22·5	
	» » 26	3300	9 miles N of Darsserort	54°37′	12°28′	2	»	XXXI	♂	20·5	21·0	
	1910 May 10	3391	4 miles E of Plantagenet Ground	54°39′	12°54′	15	»	XXXVIII	♀	29·0	34·0	Weight 405 g
	» June 12	3236	c. 6 miles S of Møen	54°51′	12°35′	13	»	XXXIX	♂	20·5	21·5	» 93 »
	» August 5	3363	c. 4 miles SE of the Island Møen	54°53′	12°36′	15	»	XXXXI	♀	20·0	24·5	» 108 »
	» Sept. 12	3338	c. 5 miles N of Darsserort	54°34′	12°30′	5	»	XXXXII	♂	20·5	23·0	» 97 »
	1911 March 5	3246	Off Arendsee, in Mecklenburg	54°11′	11°43′	39	»	XXXXVIII	♂	21·0	27·0	» 148 »
	» » 11	3393	Off Arendsee, in Mecklenburg	54°11′	11°43′	39	»	XXXXVIII	♂	22·0	24·0	» 88 »
	» May 24	3386	7 miles S of Møen	54°51′	10°36′	13	»	XXXXX	♂	21·5	23·5	» 102 »
1907 March 15	1907 March 17	3433	Old Fyrtaarnsbakke in a line with Søgaard's gardens c. 19 m	54°44′	10°38′	2	Danish	0	♂	28·0	.	
4 miles WSW of Bagenkop harbour	» » 17	3467	W of Gulstav 19 m	54°43′	10°39′	2·5	»	0	♂	25·0	23·5	
	» » 17	3468	Old Fyrtaarnsbakke in a line with Søgaard's gardens c. 19 m	54°44′	10°38′	2	»	0	♂	27·5	.	
54°43′ N	» » 17	3479	W of Gulstav	54°43′	10°39′	2·5	»	0	♂	28·5	23·5	
10°35′ E	» » 20	3450	NW of the old Lightbank, Bagenkop 11 m	54°45′	10°39′	3	»	0	♂	26·0	25·5	fresh
25 meters	» » 23	3431	1/2 mile off Dimesodde 9 m	54°45′	10°40′	3·5	»	0	♂	24·0	24·5	fresh
"Thor"	» » 23	3481	W of Fakkebjerg old Lightbank 9 m	54°44′	10°40′	3	»	0	♂	28·5	27·0	fresh
St. 891	» » 23	3496	1/2 mile off Dimesodde 9 m	54°45′	10°40′	3·5	»	0	♂	20·5	[22·0]	fresh
100 mature	» » 23	3499	1/2 mile NW of Snækkeground 17 m	54°43′	10°40′	3	»	0	♂	29·0	28·0	fresh
Plaice liber.	» » 24	3414	2 miles SW of Bagenkop harbour 13 m	54°44′	10°38′	2	»	0	♂	28·0	27·0	fresh
(No 3401-3500)	» » 24	3440	1 mile W of Bagenkop harbour 15 m	54°45′	10°39′	3	»	0	♂	27·5	27·0	fresh
	» » 25	3413	4 miles SSW of Gulstav 15 m	54°39′	10°41′	5·5	»	0	♂	28·0	27·0	fresh
"Thor"s	» » 25	3432	2 miles NW of Bagenkop harbour 15 m	54°46′	10°38′	3·5	»	0	♂	23·0	22·0	fresh
marking	» » 27	3430	Off Dimesbjerg 8 m	54°44′	10°40′	3	»	0	♂	24·5	23·0	fresh
experiment	» April 1	3417	1 mile W of Dimesodde 17 m	54°44′	10°39′	2·5	»	I	♂	22·5	[24·5]	fresh
No 2 1907	» » 1	3473	4 miles SW of Gulstav 15 m	54°40′	10°38′	3·5	»	I	♂	26·0	26·0	fresh
	» » 2	8409	1 mile W of Snækkeground 15·5 m	54°43′	10°39′	2·5	»	I	♀	27·5	27·0	fresh
	» » 2	3446	1 mile off the old Lightbank 19 m				»	I	♂	20·0	18·5	fresh
	» » 4	3410	1 mile W of Dimesodde 17 m	54°44′	10°39′	2·5	»	I	♂	23·5	24·5	fresh
	» » 4	3460	3 miles SW of Gulstav 19 m	54°41′	10°39′	3	»	I	♂	22·0	21·0	fresh
	» » 4	3486	3 miles SW of Gulstav 19 m	54°41′	10°39′	3	»	I	♂	24·0	23·5	fresh
	» » 15	3436	1 mile NW of Bagenkop harbour 15 m	54°45′	10°39′	3	»	I	♂	26·5	25·5	fresh
	» » 24	3495	1 mile NW of Dimesodde 15 m	54°45′	10°39′	3	»	I	♂	22·0	[24·0]	
	» May 6	3470	Between Fyn and Als	55°02′	10°03′	27	German	II	♂	23·5	23·0	
	» » 13	3442	1 mile S of Marstal 13 m	54°50′	10°34′	7	Danish	II	♀	23·5	23·5	
	» » 16	3449	Langelands Belt, off Albuen	54°51′	10°54′	15	»	II	♀	33·0	31·0	Tail dry

Table 5. Continued.

Particulars of Liberation. Date. Locality. No of fish. etc.	Particulars of Recovery: Date	No on Label	Locality reported	Central Position (Approximately) N.	E.	Distance between Place of Recapture and Place of Liberation, miles	Nationality of fishing vessel	No of months between Liberation and Recovery	Sex	Initial Size cm	Ultimate Size cm	Remarks
	1907 May 18	3435	1/2 mile SE of Gulstav 7·5 m	c.54°43′	10°43′	4	Danish	II	♂	25·5	25·5	fresh
	» June 12	3406	Stollerground, Kieler Fjord	54°31′	10°12′	18	German	III	♀	26·5	26·0	
	» » 21	3423	Langelands Belt 15 m			.	Danish	III	♂	28·5	29·5	
	» July 12	3421	Langelands Belt. 1 1/2 mile NW of Albuen	54°51′	10°56′	15	»	IV	♂	26·0	26·0	
	» » 23	3465	S of Langeland			.	German	IV	♂	23·0	23·0	
	» August 19	3491	5—6 miles S of Langelands South-End	54°38′	10°43′	7	»	V	♀	26·5	26·0	
	» » 22	3487	6 miles S of Langelands South-End	54°37′	10°43′	8	»	V	♂	23·0	21·0	
	» Septbr. 14	3404	W of Fehmern			.	»	VI	♂	24·0	23·0	
	1908 March 12	3461	1 mile SSW of Gulstav 17 m	54°42′	10°41′	3·5	Danish	XII	♂	24·5	24·0	fresh
	» » 19	3424	1 mile W of Bagenkop harbour 15 m	54°45′	10°39′	3	»	XII	♂	24·0	22·0	fresh
	» » 27	3478	W of Gulstav 15 m	54°43′	10°40′	3	»	XII	♀	23·0	24·0	fresh
	» April 16	3426	Ristinge Bay, 1 mile from shore 6 m	54°49′	10°37′	6	»	XIII	♀	27·5	28·0	fresh
	» June 29	3429	W of Vejsnæs 3 m	54°49′	10°25′	8·5	»	XV	♂	25·5	24·5	fresh
	» Octbr. 6	3482		54°38′	11°06′	19	German	XIX	♂	26·0	26·0	
	» ? ?	3416		?		.	Danish	XIX(?)	♀	28·0	?	
	1909 April 22	3448	1 mile SW of Gulstav 15 m	54°43′	10°40′	3	»	XXV	♂	22·0	20·5	
	» » 22	3494	NW of Bagenkop 13 m	54°46′	10°39′	4	»	XXV	♂	21·0	20·0	
	» » 24	3434	N of Bagenkop, off Hellenor 6 m	54°46′	10°40′	4·5	»	XXV	♂	28·5	28·5	
	1910 Febr. c. 15	3488	1 1/2 mile NE of Hessenstein (Hohwacht Bay)	54°23′	10°39′	20	German	XXXV	♀	23·0	.	label only
	» March 29	3456	1/2 mile W of Gulstav (caught in a fishing net)	54°43′	10°39′	3	Danish	XXXVI	♀	21·5	28·0	
1907 March 18	1907 April 14	3559	Kerteminde Bay	c.55°26′	10°43′	.	Danish	I	♂	27·5	27·0	tail dry
Entrance to the Bay of Kerteminde	» » 20	3505	2 miles S of Romsø 23 m	55°29′	10°50′	4·5	»	I	♂	28·0	28·0	
	» » 20	3514	E of Møllegrunden, Kerteminde	55°27′	10°46′	2	»	I	♀	24·0	24·5	
	» » 30	3548	2 miles S of Romsø	55°29′	10°50′	4·5	»	I	♀	28·0	27·0	
	» » c. 30	3595	At Kerteminde	55°27′	10°41′	3·5	»	I	♀	25·0	25·0	
55°25′ N 10°46′ E	» May 2	3568	Off Kerteminde Bay 16 m	c.55°25′	10°47′	.	»	II	♀	36·0	36·0	
	» » 4	3598	Kerteminde Bay	c.55°26′	10°43′	.	»	II	♀	29·0	29·0	tail a little dry
17 meters	» » 8	3504	W of Møllegrunden	55°27′	10°45′	2	»	II	♀	24·0	25·5	
"Thor"	» » 8	3582	Off Risingehoved	55°25′	10°44′	1	»	II	♀	26·0	26·0	
St. 895	» » 12	3569	c. 2 miles NW of Sprogø	55°21′	10°56′	7	»	II	♀	35·5	35·0	
100 Plaice liber.	» » 14	3532	Great Belt, 1 mile W of Egholm	55°15′	11°08′	16	»	II	♀	35·0	.	
	» » c. 15	3517	E of Risingehoved	55°25′	10°44′	1	»	II	♂	25·5	25·0	
(No 3501-3600)	» » c. 15	3520	E of Risingehoved	»	»	1	»	II	♀	25·5	24·5	
"Thor"'s marking experiment No 3 1907 all plaice mature (exc. ♀ 24 cm)	» » c. 15	3549	E of Risingehoved	»	»	1	»	II	♀	26·5	27·0	
	» » c. 15	3555	E of Risingehoved	»	»	1	»	II	♂	21·0	21·0	
	» » c. 15	3579	E of Risingehoved	»	»	1	»	II	♀	28·0	28·0	
	» » 19	3528	Off Risingehoved	»	»	1	»	II	♂	28·5	.	
	» » 19	3545	2 miles off Kerteminde harbour	55°27′	10°43′	2·5	»	II	♀	23·5	24·0	dry
	» » 19	3557	2 miles off Kerteminde harbour	»	»	2.5	»	II	♀	24·0	24·0	dry
	» » 20	3524	Close S of Kerteminde Bay	c.55°24′	10°47′	.	»	II	♀	31·0	29·5	
	» » 23	3590	E of Møllegrunden	55°27′	10°46′	2	»	II	♂	26·0	26·0	
	» June c. 3	3580	Off Charlottenlund. North side of Langeland	55°10′	10°55′	16	»	III	♀	28·5	29·0	tail dry
	» » 5	3566	Risingehoved, Kerteminde Bay	55°25′	10°44′	1	»	III	♀	25·5	25·0	tail dry
	» » ?	3543				.	»	III	♀	31·0	32·5	
	» July 10	3563	E of Kløverhagen, Nyborg	55°14′	10°50′	12	»	IV	♀	32·0	36·5	
	» » c. 22	3519	W of Omø Light 15 m	55°10′	11°05′	18	»	IV	♀	26·0	25·5	
	» » 22	3542	Off Egholm 38 m	55°15′	11°06′	15	»	IV	♀	24·5	25·5	
	» » 26	3534	1 mile NE of Thurø Reef	55°02′	10°45′	24	»	IV	♀	30·0	31·0	
	» » 29	3526	Stillinge Bay	55°26′	11°10′	13	»	IV	♀	30·5	29·0	
	» August 1	3506	1 mile off Kongshøj 23 m	55°13′	10°50′	13	»	V	♀	25·5	28·5	
	» » 1	3518	4 1/2 miles NW 3/4 N of Sprogø Light	55°23′	10°53′	4·5	»	V	♀	35·0	36·5	
	» » c. 10	3574	Off Botofte Light 18 m	54°59′	10°56′	28	»	V	♀	34·5	34·5	

Table 5. Continued.

Particulars of Liberation. Date. Locality. No of fish. etc.	Particulars of Recovery											Remarks
	Date	No on Label	Locality reported	Central Position (Approximately) N.	E.	Distance between Place of Recapture and Place of Liberation, miles	Nationality of fishing vessel	No of months between Liberation and Recovery	Sex	Initial Size cm	Ultimate Size cm	
	1907 Aug. 22	3564	Østerrenden between Sprogø and Korsør	55°20′	11°03′	11	Danish	V	♀	32·0	32·0	
	1908 March 27	3538	Musholmsflakket	55°28′	11°05′	11	»	XII	♀	31·0	35·0	
	» April 22	3561	Great Belt, 2 miles off Risingehoved	55°26′	10°47′	1	»	XIII	♀	28·5	30·0	Tail dry
	» May 27	3511	Close N of Halskov Reef 9 m	55°21′	11°04′	11	»	XIV	♀	30·0	32·5	
	» June 28	3587	1 mile N of Knudshoved (at Nyborg)	55°19′	10°51′	7	»	XV	♀	27·0	31·5	
	» July 2	3523	6 miles S of Sprogø 23 m	55°14′	11°00′	14	»	XVI	♂	26·5	27·0	
	» » 25	3513	NW of Egholm, W Side of Østerrenden	55°17′	11°05′	14	»	XVI	♀	32·0	33·5	
	1909 April 10	3593	Off Nordenhuse	55°23′	10°47′	2	»	XXV	♀	29·0	30·5	tail dry
	» May 5	3508	3 miles W of Musholm	55°28′	11°00′	8·5	»	XXVI	♀	42·5	c.45·0*	* fide fisherman
	» » 29	3556	Off Spodsbjerg on Laalandsflak 17 m	54°55′	10°55′	32	»	XXVI	♀	34·0	43·0	fresh

B. The supposed migrations of the plaice from the Kattegat through the Sound to the true Baltic.

By an investigation of the average size of specimens of the different annual series of plaice REIBISCH has — as before mentioned — obtained the result that the older series of plaice in region III (See Chart Fig. 1) are, on an average, a little smaller than specimens of the same age in region IV. Reibisch explains this fact by the presumption that a great number of proportionately rapidly growing plaice immigrate to region IV from the Kattegat through the Sound. According to my opinion it is more natural to seek for the explanation of this (possible) difference in size in the fact that a far more strenuous fishing takes place in region III than in region IV. In the course of a year ca. 40 à 50 percent of the marked plaice were recaptured in region III and only c. 10 à 15 percent in region IV[1].

By the strenuous fishing it is in the first place the large specimens which are taken away, and experience has shown that there are proportionately many rapidly growing fish among these[2]. Old dwarf-forms which are so small that they can pass through the meshes of the gears, or which are not considered good enough to take to market, will on the contrary be allowed to continue their existence even in those districts of the Belt Sea and Baltic which are subjected to strenuous fishing.

If an immigration on a large scale took place from the Kattegat through the Sound to the true Baltic, as Reibisch supposes, it would appear in the numerous Swedish and Danish marking experiments with plaice in the Kattegat, but we do not know any single example of the circumstance that plaice marked and liberated in the Kattegat were recaptured later on in the true Baltic. Not even from the Danish and Swedish marking experiments carried out at the northern entrance of the Sound do we know a single example of a plaice having passed through the Sound to the true Baltic. From these facts we dare undoubtedly conclude that migrations of this kind cannot take place to any great extent.

[1] A. C. JOHANSEN: Bericht über die Eier, Larven und älteren Stadien der Pleuronectiden in der Ostsee nach Zahle, Grösse, Alter und Geschlecht. Rapports et Procès-verbaux des Réunions etc. Vol. XII No. 7 1910.

[2] See f. i.: A. C. JOHANSEN: Über die Schollenfischerei im Kattegat und die Mittel, sie zu heben 1908.

IV. Dr. Reibisch's evidence to show that the stated number of plaice larvæ in the true Baltic would not be sufficient for the renewal of the stock.

On the basis of a series of fishing experiments which were carried out under the direction of the author in the spring of 1908, I calculated that more than 900 millions of pelagic plaice larvæ existed in the true Baltic at that time[1]. Reibisch considers it justifiable, according to the information to hand, to suppose that a similar quantity of larvæ as calculated by me was present, but puts forth a few objections which might tend to reduce the number somewhat, so that the 900 millions could no longer be considered as a minimum figure, but as a rather liberally calculated number. Reibisch thus puts forth that in water of 7—8 ‰ S the plaice were almost entirely found where bottom-water of a considerably higher salinity occurred, the main part of the water volumes between 7—8 ‰ S in shallow water would thus hardly contain any larvæ, and I have for these parts reckoned with the same quantity of larvæ as for the water volumes of the same salinity reposing on a lower layer of greater salinity. — It is possible that future investigations will show that Reibisch is right in this view, but the material to hand is hardly sufficient to justify a distinction of this kind. — Reibisch remarks moreover, that we really ought to reckon the whole Kadet Channel in the western Baltic and not — as several other authors as well as I myself have done — consider the straight line between Gedser and Darsserort as the limit between the two waters.

The Kadet Channel itself is a boundary area between the western and the true Baltic. It is however probable that Reibisch is right in his remarks, that the fauna in the Kadet Channel more resemble the fauna in the western Baltic than the fauna in the Arkona basin, and if so it would be natural to reckon the Kadet Channel in the western Baltic.

If the objections put forth by Reibisch may possibly tend to reduce somewhat the "minimum figure" which I have put down, it is easy to refer to other facts which point in the opposite direction, and which justify the fact that I have indicated the number of larvæ calculated by me as a minimum figure.

1) I have taken into my calculation that the trawl filters the whole water volume which it comes across on its way in the water, while it is certain that a considerable part of this water does not get filtered, perhaps about $^1/_3$—$^1/_2$ on an average.
2) It should be remembered that in the period during which I undertook my investigations — though this presumably was the most favourable period — there were still some plaice eggs in the water, and some larvæ had possibly already reached the bottom stage. It is thus quite certain that the total number of plaice larvæ which were hatched in the spring of 1908 were not floating in the water at the time when I undertook my investigations.
3) It is probable that some of the very youngest stages have passed through the meshes of the trawl. The size of each of the four sides of the meshes was 1·6—1·8 mm.
4) It is probable that some of the older larval stages owing to their movements have escaped the fishing apparatus.
5) Finally it should be noticed that some of the captured small larvæ have probably been overlooked, as they easily remain hanging in an apparatus as big as the young fish trawl.

We will now examine more closely Prof. Reibisch's reasons for supposing that the quantity of larvæ which I have calculated for the year 1908 as at least 900,000,000, would be insufficient for the renewal of the stock.

Among Dr. Reibisch's calculations and arguments there are several to which I can give my approval.

[1] A. C. Johansen: Contributions to the biology of the Plaice. IV. 1908.

When Reibisch estimates the stock of mature plaice in the true Baltic at ca. 50,000,000 and considers this figure rather too low than too high, I agree with him in this. When he moreover estimates that among 1000000 mature specimens we find ca. 600000 males and ca. 400000 females I have no objection either to these figures.

On the contrary where Reibisch calculates the percentage of the yearly waste in the stock of mature specimens and the percentage of the daily waste in the quantity of eggs and in the stock of pelagic larvæ, I do not agree with him.

Reibisch calculates a yearly waste of 50 % for the mature specimens. It is true that he remarks that this is too highly estimated according to his own investigations (p. 191), but in his calculations we meet continually with this 50 %.

According to Reibisch's investigations the number of specimens of the various annual series which he has found in the true Baltic in 1908 and 1909 is as follows (p. 162):

Annual series:

	07,	06,	05,	04,	03,	02,	01,	00,	99,	98,	97,	96,	95
♂	1	12	22	63	92	72	65	46	18	10	1	—	—
♀	2	26	9	12	50	24	21	8	16	4	4	5	1
♂+♀	3	38	31	75	142	96	86	54	34	14	5	5	1

The reason of the fall towards the left side from the annual series 1903 is, that a continually greater percentage of the specimens have passed through the meshes of the fishing apparatus. The reason for the fall towards the right side from the series 1903 must be looked for in the yearly waste (Zehrung).

The figures stated do not justify the supposition of a yearly waste of 50 % or about this. A yearly waste of 33 1/3 percent corresponds better with these figures, and when we to this add the facts mentioned in the introduction, that the specimens from the series from 1904 or 1903 and still earlier probably ought to have been distributed over many more annual series, it seems to be ample, when we reckon with a yearly waste of 33 1/3 %.

If we reckon with a yearly waste of 33 1/3 % in 8 years instead of 50 % in 6 years, many of Reibisch's figures must undergo an essential change.

According to Reibisch's calculations (taking a yearly waste of 50 % for granted) a stock of 1000000 mature specimens consists:

of fish	of the first	mature series	507940
- — - -	second	— —	253970
- — - -	third	— —	126980
- — - -	fourth	— —	63490
- — - -	fifth	— —	31750
- — - -	sixth	— —	15870

If we reckon with a waste of 33 1/3 % in 8 years, 1000000 mature specimens will be distributed in the following way:

Fish	of first	mature series	346868
— -	second	— —	231245
— -	third	— —	154163
— -	fourth	— —	102776
— -	fifth	— —	68517
— -	sixth	— —	45678
— -	seventh	— —	30452
— -	eigth	— —	20301

If we suppose that among these 1000000 mature specimens the 400000 are females, it will be necessary for the renewal of the stock that so many plaice are hatched from the eggs of these females in one spawning season, that 346868 specimens reach the first mature series. This means that the renewal of the stock is secured, when 35 specimens, reaching maturity, come forth from the eggs of 40 mature plaice in one spawning period.

If we now suppose that 50 millions of mature plaice exist in the Baltic, of which 30 millions are males and 20 millions females, it will be sufficient for the renewal of the stock if so many specimens are hatched in one spawning period that 17·5 millions reach maturity. The corresponding figure which Dr. Reibisch gives according to his calculations is 25 million specimens.

Reibisch estimates that the plaice larvæ which I caught in the beginning of May 1908 in the true Baltic had an average age of ca. 3 months reckoned from the spawning time.

I consider this age estimate quite reasonable and assume that 2 of the 3 months must be reckoned for the age of the larvæ, while one month goes to the hatching of the eggs. Hereby is reckoned with a mean temperature of ca. 3° C. in the lower layers in the Baltic and especially in the Arkona basin, during the months from January to April[1].

Dr. Reibisch observes moreover (p. 193):

"Für die Rechnung besagt diese Annahme, dass 909 Millionen Larven im Jahre 1908 wirklich das Alter von 3 Monaten erreicht haben. Ferner sei noch vorausgesetzt, dass im allgemeinen nach einem weiteren Monat, d. h. 4 Monate nach der Ablage als Ei, die Larven zum Bodenstadium übergehen. Für die östliche Ostsee ist hiernach im Jahre 1908 der Höhepunkt des Laichens auf Anfang Februar verlegt, die Mehrzahl der jungen Fischen hätte Anfang Juni ihre Metamorphose so weit vollendet, dass sie in das Bodenstadium übergegangen wäre. Das wird nicht allzusehr von den tatsächlichen Verhältnissen abweichen. Aus den 909 Millionen Schollenlarven der östlichen Ostsee müssten sich zur Erhaltung des Bestandes in diesem Gebiete 25 Millionen laichreife Schollen entwickeln, und zwar in einem Zeitraum von 3 Jahren und 9 Monaten. Die prozentuale Zehrung z lässt sich nach der Gleichung bestimmen

$$z = 100\left(1 - \sqrt[n]{\frac{B}{L}}\right)$$

wobei n die Zeit, in der die Larvenzahl L auf die Anzahl B der Bodenstadien reduziert wird. Für die östliche Ostsee berechnet sich hiernach die durchschnittliche jährliche Zehrung vom Ende des 3. Monats bis zum Beginn der ersten Laichperiode zu 61, 64 % jährlich".

I can on the whole agree with these remarks if we in accordance with my above mentioned calculations change the figure 25 millions to the figure 17·5 millions. The yearly percentage of waste will according to this be 65·12 %.

It is however Reibisch's opinion that the waste is far greater already in the western Baltic. On the basis of Prof. Apstein's investigations he estimates the daily waste of plaice eggs in the western Baltic to be ca. 3 % (See p. 194). Secondly he supposes the same waste to take place with regard to the larvæ till they have reached an age of 3 months (calculated from the hatching of the eggs). — Moreover he estimates the average number of eggs pr. plaice to be 50000 and calculates that a daily waste of 3 % of eggs and larvæ after 3 months would leave 3224 larvæ. As Reibisch moreover starts from the point of view that so many plaice are hatched from the eggs of 4 females that 5 of these reach maturity, he calculates according to this the yearly waste for the time from the age of 3 months to the age of 4 years to be 87·69 %. —

[1] Comp. Bulletin trimestriel. Cons. perm. internat. Année 1906—1907. Partie supplementaire. p. 10—13.
and Johan Gehrke: Beiträge zur Hydrographie des Ostseebassins. Publications de Circonstance No. 52. Cons. perm. internat. 1910.

Reibisch has obtained this figure from the equation:

$$z = 100\left(1-\sqrt[15]{\frac{5}{3224\times 4}}\right)$$

To these arguments I will make the following remarks:

I have no objection to the fact that the average number of fertilized eggs pro female plaice in one spawning season is calculated at 50000 for the western Baltic. I agree with Reibisch that this estimate is rather too low than too high. It is however of vital importance that Reibisch has quite misunderstood Prof. Apstein's results when he estimates the daily waste of plaice eggs in the western Baltic to be ca. 3 %. Apstein has calculated the average waste per "day degree" (Tagesgrad)[1] at ca. 3 % and Reibisch has now made the mistake of reckoning with the waste per day instead of per "Tagesgrad". Apstein writes about the way in which he has made his calculations as follows (p. 244).

"Um die Zehrung nach der Zinseszinsrechnung zu berechnen, bezeichne ich ein Stadium als Endkapital (K), z. B. Dorsch $K = 68$, dann das folgende Stadium Ej als Anfangskapital (a); $a = 27$ und als n die Tagesgrade, die Stadium K braucht. Nach der Formel

$$p^1 = 100 \cdot \text{num}\left(\frac{lg\,K - lg\,a}{n}\right) - 100$$

berechne ich die Prozente, die hier also die Zehrung bedeuten. Ich erhalte dann:

	Scholle	Flunder	Dorsch	Sprott
L.....	—	—	—	—
Ea	4·45	—	2·85	
Ep	3·36	14·9	2·5	sehr
Ej.....	2·35	8·14	3·6	gross
K.....	?	?	2·68	
Mittel...	3·39	11·52	2·91	— "

From this it will be seen quite clearly that Apstein's calculations regard the waste per "day degree" and not the waste per day, and the figures which he has used in his calculations confirm this completely. Now we have only one case in which we are justified in reckoning the number of days and the number of "day degrees" equally, namely, where the temperature is just 1° higher than the biological zero for the development of the plaice egg. The biological zero for the development of the egg lies according to Reibisch[2] at ÷ 2·4° C. and at a temperature of ÷ 1·4° C. the number of "day degrees" and the number of days will be identical. According to Apstein's investigations the plaice egg requires 164 "day degrees" for its development, and at a temperature of ÷ 1·4° C. the development of the egg should thus take 164 days. The temperature which we find in the western Baltic — as well as in the eastern Baltic — during the development of the majority of the plaice eggs — is however several degrees above ÷ 1·4° C. and Dr. Reibisch's calculations thus lead to quite wrong results.

[1] The degree of development of an egg is measured in "day degrees" (Tagesgraden), it is the product of the mean temperature (expressed in Centigrades and reckoned from the "biological zero" for the development of the egg) and the number of days passed since the fertilization of the egg. One single "Tagesgrad" thus corresponds to a certain fraction of the time necessary for the development of a fish egg, for the plaice according to Apstein to $^1/_{164}$. If the temperature is only 2 degrees above the biological zero, the development of the eggs will take 82 days, if the temperature is 4 degrees above the said zero, the development will take 41 days.

[2] J. Reibisch: Ueber den Einfluss der Temperatur auf die Entwicklung von Fischeiern. Wissensch. Meeresunters. N. F. Bd. 6 Abt. Kiel 1902.

The plaice eggs which are developed during the very coldest season in the western Baltic will here on an average meet a temperature of 1·5°—2° C.[1]. If we reckon with a temperature of 1·6° C. the development of the plaice egg will according to Apstein (l. c.) take 41 days. The plaice eggs which are subjected to the highest temperature in the western Baltic become developed at the end of April and in the beginning of May at a mean temperature of between 5° and 7° C.[2]. If we reckon with a mean temperature of 6° C. for these eggs, their hatching will take 20 days. According to the figures here stated it will be seen that we are not far wrong if we reckon the time which the hatching of the plaice eggs requires at ca. 1 month on an average. This will correspond to a mean temperature of ca. 3° C. during the development of the eggs, which cannot be far from the real conditions.

According to Apstein's calculations — to which however many objections may be raised[3] — 171·3 eggs of the youngest stage (*u*) are on an average required for the hatching of 1 plaice larva in the western Baltic, 160·3 eggs of the stage *K* (Blastoderm), 63·1 of the stage *Ej* ("Embryo young"), 19·3 in the stage *Ep* ("Embryo pigmented") and 3·7 in the stage *Ap* ("eyes pigmented"). To this is however to be remarked, that the larvæ, which Apstein is alluding to, are not newly hatched larvæ, but larvæ of a certain age (perhaps an age of a month or more). — If we thus suppose that the waste from 171·3 to 1 takes place in 31 days, we get a higher limit for the same, as the larvæ is supposed to be newly hatched. We have here for the calculation of the daily waste the following equation:

$$z = 100\left(1 - \sqrt[31]{\frac{1}{171{\cdot}3}}\right)$$

or $z = 15{\cdot}29\ ^0/_0$.

A lower limit for the daily waste of the eggs (under the presumption that their development takes 31 days) we can find when we start from the assumption that the number of larvæ which are hatched can at the highest be as great as the number of eggs in the oldest developmental stage („eyes pigmented"). It will in reality always be considerably lower. If we suppose that the waste from 171·3 to 3·7 takes place in 31 days we obtain the daily waste:

$$z = 11{\cdot}64\ ^0/_0.$$

The daily waste of the eggs must thus be supposed to lie between 11·64 % and 15·29 % when we start from the point of view that Prof. Apstein's figures are available.

If we now put 11·64 per cent instead of the 3 % in Dr. Reibisch's before mentioned calculation (p. 23) we obtain the number of the remaining larvæ (A_n) from the 50000 eggs (*a*) after 3 months (90 days) of the following equation:

$$A_n = a(1 - r)^n = 50000\,(1 - 0{\cdot}1164)^{90} = 0{\cdot}73.$$

The corresponding figure which Reibisch found because he had reckoned with days instead of "day degrees" was 3224. If we continue the calculation according to Prof. Reibisch's scheme in order to find the yearly average waste for the plaice from 3 months up to the age of 4 years, we obtain as follows:

[1] J. P. Jacobsen: Mittelwerte von Temperatur und Salzgehalt in dänischen Gewässern 1880—1907. Meddelelser fra Kommissionen for Havundersøgelser. Serie Hydrografi Bd. 1. 1908.

[2] It is still an open question whether some of the very early spawned plaice eggs become developed in the western Baltic in November and December.

[3] A certain sifting of Prof. Apstein's material would assuredly have been desirable. It would have been better to base the calculations on the waste of the eggs only on the material procured by vertical hauls. The different stages of development of the eggs are not distributed equally in all layers of the water. The older stages are the most heavy and float proportionately deep in the water. Even if we undertake horizontal hauls in the upper as well as in the middle and the lower layers, we have not such good chances of obtaining a good picture of the frequency of the different developmental stages of the eggs as by vertical hauls. It is not even certain that the vertical hauls give an absolutely true picture of the frequency of the various stages of development. There is a possibility that some eggs being on the bottom or very near the bottom will not be captured by the Hensen net, and among such eggs proportionately many will belong to the older stages of development.

$$z = 100\left(1 - \sqrt[15]{\frac{5}{0{\cdot}73 \times 4}}\right) = \div 15{\cdot}4$$

That Reibisch cannot use this result to prove that the number of larvæ which I calculated for the true Baltic in 1908 is too small for the renewal of the stock, is evident!

The main reason why the number of larvæ obtained is too low and the percentage obtained for the yearly waste is negative, is that the above mentioned great waste of the eggs — in accordance with Reibisch's reasoning — is also supposed to hold good for the larvæ. It is however probable that if Reibisch had noticed that the daily waste of the eggs according to Apstein's investigations should have been put down to a similar figure as stated by me, he would have given up reckoning with the same waste for the larvæ.

In a calculation to show how far the quantity of pelagic plaice larvæ occurring in the true Baltic is sufficient for the renewal of the stock of plaice in this sea, there will as yet be too many uncertain factors: The size of the stock of plaice is uncertain, the percentage of the yearly waste of older specimens is uncertain, and the percentage of the daily waste for the eggs and larvæ is uncertain. It is moreover uncertain, how much the minimum number calculated for the pelagic plaice larvæ in the Baltic in the spring of 1908 is too low. Finally, we do not know as yet how far the quantity of plaice larvæ occurring in the Baltic in the beginning of May 1908 was larger or smaller than normally.

V. On the relative frequency of the individuals of the two sexes in the western Baltic and the true Baltic.

In the western Baltic, Franz has found that ca. 53 % of the 0 group of the plaice are males and ca. 47 % females. These figures are based on investigations of 855 specimens of which he has been able to determine the sex with perfect certainty.

In the true Baltic I have determined the sex of 548 specimens of the I group (See Table 1 p. 9), and it appeared here that 299 specimens or 54·6 percent were males and 249 specimens or 45·4 per cent were females[1]. The percentages found by Franz and by myself for the males and females thus closely correspond with each other, and Franz has found a similar percentage for young specimens in the south eastern part of the North Sea[2].

While we in the captures of the 0 Gr. and the I gr. continually notice that both sexes are well represented, we shall for the older series frequently find that either the males or the females are present in quite predominant numbers. It becomes thus very difficult to form an idea concerning the relative frequency of males and females in a certain area for the older specimens.

The fact that the females have a much quicker growth than the males causes naturally that many more per cent of females than of males occur among the large specimens, while many more males than females are found among the small mature specimens. In the western Baltic and in the true Baltic we find that nearly all specimens exceeding 33 cm are females, while the majority of the specimens between 15 and 26 cm are males.

[1] In the 0-gr. of the plaice I have in March 1907 found among 119 specimens 43 females and supposed the rest (76 specimens) to be males. I have however not in all cases observed the testes, so I do not feel certain concerning the exactness of the determination.

[2] Viktor Franz: Die Eiproduktion der Scholle. Wissensch. Meeresunters. N. F. Bd. IX Abt. Helgoland 1908.

The circumstance that a great number of the old mature males in the Baltic are only of slight size and of low market value, while the females on an average are of a far more considerable size and market value, causes naturally that the females in the Baltic suffer by the fishery to a far greater extent than the males, and here we have to do with a continuously working factor contributing to give the stock of males existing in the sea a numerical predominance over the females.

An example may here be stated showing how the females suffer by the fishery as compared with the males. Some Danish fishing experiments were carried out on April 19th 1911, south of Skjoldnæs, Ærø, at a depth of from 7—19 meters. In one case the usual Danish gear the "Snurrevaad" without an extra net was employed, and the capture was assorted, so that the fish was above the Danish minimum size. Among 173 specimens examined 51 were males and 122 females. In the other case the end of the "Snurrevaad" was covered by a fine meshed extra net, and of 250 specimens examined 218 were males and 32 females. The percentage had thus altered from 70·5 % females and 29·5 % males to 12·8 % females and 87·2 % males.

The fishing in the western Baltic is carried on much more intensively than in the true Baltic, and we have here a factor tending to reduce the percentage of females in the western Baltic more than in the true Baltic. The quantity of young specimens which yearly grow up to a "marketable size" is on the other hand proportionately far more considerable in the western Baltic than in the true Baltic, and this acts in the opposite direction.

There is no doubt that the females are relatively more frequent in the shallow water from the coast up to 15 to 20 meters depth than in deeper water. The following may account for this feature:

1) When the plaice approach maturity they show a more pronounced tendency to migrate away from the coast than the immature specimens do. An essential proportion of the males become mature at an earlier age than the females, and proportionately more females than males consequently remain in the neighbourhood of the coast.
2) The spawning period for the individual male lasts much longer than that for the female, and as long as the spawning lasts the plaice show a tendency to stay in deeper water, whilst when it is over they show a tendency to migrate into more shallow water.

The same two circumstances which cause the females to be proportionately numerous in shallow water must cause them to be proportionately few in deeper water.

In which of the deeper basins in the western Baltic (see Fig. 5) and in the true Baltic (see Fig. 1) the males predominate most over the females is still an open question, but the information to hand suggests however that in the basin between Laaland and Mecklenburg and in the Arkona basin the females on an average constitute a considerably higher percentage of the stock than in the deeper parts of the western Baltic and in the Bornholm basin.

In the relative frequency of the individuals of males and females in the waters between Laaland and Mecklenburg (Region III Fig. 1) and in the true Baltic (Region IV) I see nothing to support the supposition that the main proportion of the males in contradistinction to the females should have immigrated to these waters. The majority of the stock of plaice in the true Baltic occurs no doubt in the part of the sea west of Bornholm, and it is not probable that the percentage of males here should be abnormally high in comparison with the percentage of males in Reibisch's regions I and II in the western Baltic.

The most important of the material which has been at my disposal for the determination of the relative frequency of the specimens of the two sexes in the western and in the true Baltic I have drawn up on table 6. Here I have not taken into consideration the specimens below a length of 13 cm. With regard to the relative frequency of males and females among the younger specimens I can refer to my remarks on the 0-gr. and the I gr. on p. 8.

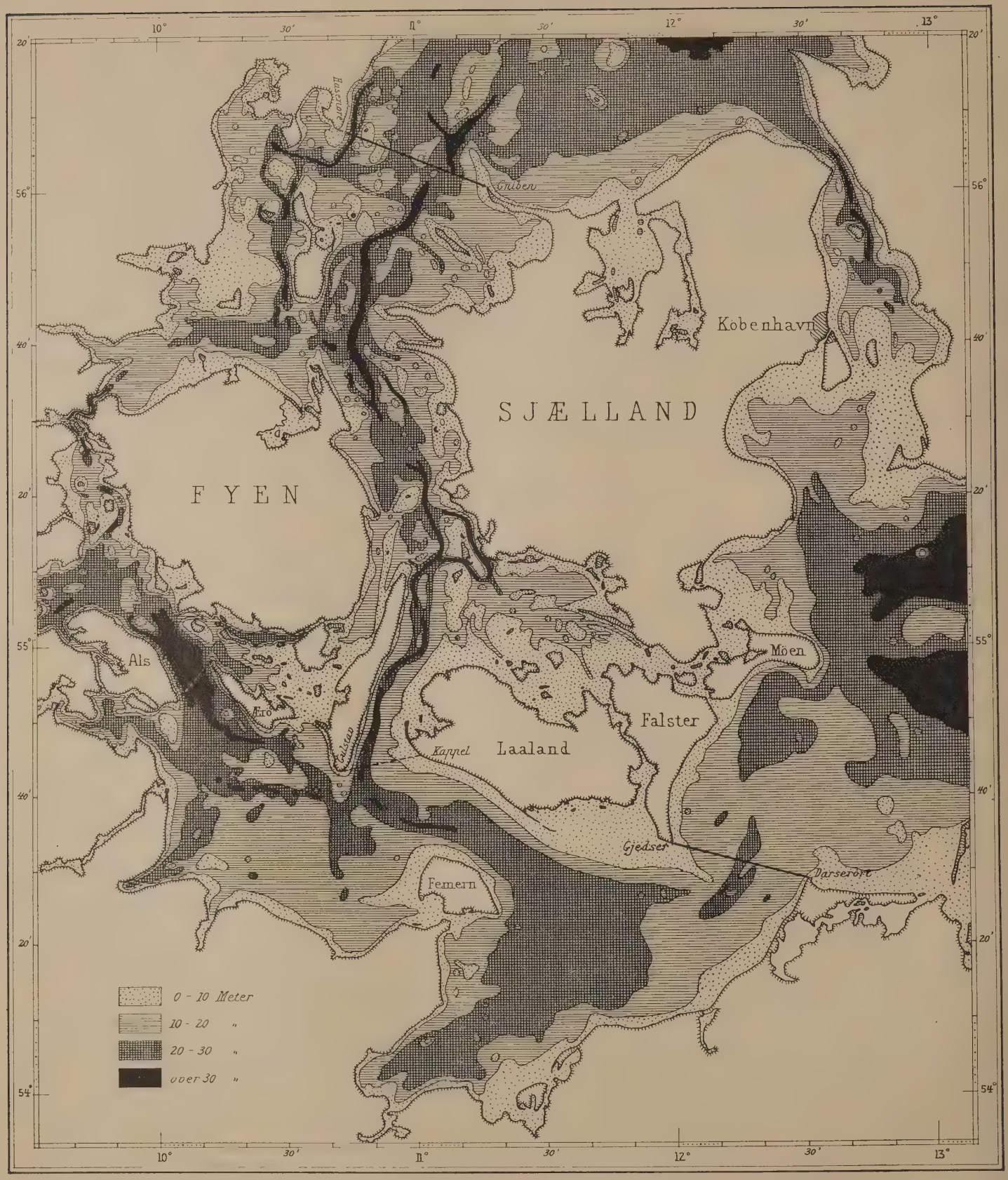

Fig. 5. The depths in the Belt Sea. The greatest depth known in the Belt Sea is 81 meters (Little Belt west of Fænø).

With regard to the information in Table 6 concerning the number of captured males and females, it should be remarked that where proportionately wide meshed gears have been employed, such as gill nets and Snurrevaad, it must be regarded as probable that proportionately many males have passed through the meshes. Where sorting has taken place after the capture and the small specimens have been thrown away, proportionately many males will as a rule become lost. The importance of this last feature is shown by a statement of Trybom, who in a capture in the Bornholm deep found 36 males and 14 females among 50 specimens of a length of 24—34 cm, but not a single female among 30 specimens of 14—24 cm.

Table 6. On the percentage of males and females in the captures of plaice in the western Baltic and the true Baltic.
(Only specimens of more than 13 cm in length are taken into consideration).

Area	Locality	Depth meters	Date	Number ♂	Number ♀	Percentage ♂	Percentage ♀	Size-limits	Fishing Apparatus	Investigator or Authority
Coastal grounds at South Funen and Langeland and Ærø 0—19 Meters	Off Dyreborg, Funen		Febr.& March 1892	66	923	6·7	93·3	20—40	Gill-nets and weels	C. G. Joh. Petersen
	Off Tranekær, Langeland	16	March 17 1907	12	19	38·7	61·3	18—38	50 f. Otter trawl	A. C. Johansen
	- — —	9	April 6—10 1909	17	186	8·4	91·6	14—49	Snurrevaad	—
	Off Lundeborg, Funen	15	» 13—15 »	58	213	21·4	78·6	14—44	—	—
	Off Skjoldnæs, Ærø	7—19	» 19 »	218	32	87·2	12·8	14—29	Snurrevaad with fine-meshed extra codend	A. Otterstrøm & A. C. Johansen
			Total...	371	1373	21·3	78·7			
Deep Basin Western Baltic	WSW of Bagenkop, Langeland	25	March 15 1907	216	38	85·0	15·0	15—33	50 f. Otter trawl	A. C. Johansen
	SSW of Bagenkop, Langeland	22	April 16—17 1909	817	146	84·8	15·2	13—36	—	—
	Between Als and Ærø	.	Septbr. 1907	540	59	90·2	9·8	.		Strodtmann
	SW of Bagenkop, Langeland	21	Novbr. 13 1905	57	22	72.2	27·8	18—37	50 f. Otter trawl	A. C. Johansen
			Total...	1630	265	86·0	14·0			
Fehmern Belt to Kadet-Channel	Fehmern Belt 54°36'N 11°06'E	25	May 17 1904	146	60	70·9	29·1	.	90 f. Otter trawl	Strodtmann
	Kadet Channel c.55°35'N 12°25'E	20	August 9 1905	619	363	63·0	37·0	.	—	—
	Off Travemünde	.	Septbr. 9 1905	240	95	71·6	28·4	.		—
			Total...	1005	518	66·0	34·0			
Coastal Grounds off Stevns. Sealand	Off Stevns		Febr. 28 1892	6	11	35·3	64·7	21—27	Gill nets	C. G. Joh. Petersen
	- —		April 1892	66	103	39·1	60·9	17—34	—	—
			Total...	72	114	38·7	61·3			
Plateau between Falster, Møen and Rügen	Rytsebæk, Møen		Febr. 18 1892	1	39	2·5	97·5	22—30		C. G. Joh. Petersen
	54°39'N 12°29'E	17	March 13 1907	1034	218	82·6	17·4	13—32	50 f. Otter trawl	A. C. Johansen
	54°48'N 12°23'E	22	» 14 »	173	25	87·4	12·6	13—30	—	—
	54°43'N 12°10'E	15	» 14 »	203	23	89·8	10·2	13—30	—	—
	W of Møen	23	» 23 1903	100	76	56·8	43·2	18—30	—	—
	55°35'N 12°12'E	17	» 24 1907	397	149	72·7	27·3	13—30	—	—
	Off Zingst	14	» » »	4	23	14·8	85·2	13—39	—	—
	54°52'N 12°25'E	17	» 26 »	131	108	54·8	45·2	13—34	—	—
	54°47'N 12°43'E	18	» » »	59	68	46·5	53·5	13—33	—	—
	54°37'N 12°25'E	15	July 17 »	15	8	65·2	34·8	13—32	Young fish trawl	—
	S of Møens Klint	18	» 21—24 1905	46	54	46·0	54·0	20—40	Snurrevaad	Trybom & Kaudern
	54°52'N 12°25'E	17	August 2 1907	80	49	62·0	38·0	13—27	50 f. Otter trawl	A. C. Johansen
	54°39'N 12°29'E	17	» 3 »	13	2	86·7	13·3	16—23	Young fish trawl	—
	54°50'N 12°48'E	21	» 3 »	44	16	73·3	26·7	13—27	—	—
	54°49'N 12°47'E	19	» 3—4 »	38·	12	76·0	24·0	13—29	—	—
	S of Møen	26	Septbr. 2—5 1902	c.1465	c. 790	c.65·0	c.35·0	13—35	Otter trawl	Petersen & Schmidt
	54°49'N 12°18'E	22	Novbr. 16 1905	41	32	56·2	43·8	13—32	50 f. Otter trawl	A. C. Johansen
	54°54'N 12°26'E	21	» » »	392	103	79·2	20·8	13—30	—	—
			Total...	4236	1795	70·2	29·8			

Table 6. Continued.

Area	Locality	Depth meters	Date	Number ♂	Number ♀	Percentage ♂	Percentage ♀	Size-limits	Fishing Apparatus	Investigator or Authority
Arkona-Basin	54°52′N 13°44′E	47	March 25 1907	32	13	71·1	28·9	14—34	50 f. Otter trawl	A. C. Johansen
	55°07′N 12°42′E	30	» 26 »	129	24	84·3	15·7	13—31	—	—
	55°08′N 13°06′E	36	» » »	6	5	54·5	45·5	17—32	—	—
	c. 54°45′N 13°16′E	35—36	August 8 1905	134	90	59·8	40·2		90 f. Otter trawl	Strodtmann
			Total...	301	132	69·5	30·5			
Plateau between Bornholm, Rügen and Pommern	54°32′N 14°04′E	17	March 25 1907	9	16	36·0	64·0	13—34	50 f. Otter trawl	A. C. Johansen
	54°21′N 14°56′E	14	July 23 »	2	5	28·6	71·4	19—30	Young fish trawl	—
	54°58′N 14°37′E	17	» 25 »	3	2	60·0	40·0	19—32	—	—
	54°57′N 14°48′E	14	» 30 »	69	27	71·9	28·1	13—50	50 f. Otter trawl	—
	54°30′N 13°50′E	16	» 31 »	3	3	50·0	50·0	18—27	—	—
	54°38′N 13°49′E	24	August 1 »	2	9	18·2	81·8	14—27	Young fish trawl	—
			Total...	88	62	58·7	41·3			
E of Skaane and Blekinge	S by E of Karlshamn	28	July 16 1909	19	142	11·8	88·2	21—30		Trybom & Övergaard
	SW of Utklippan	48	» 19 1908	18	7	72·0	28·0	15—32		Trybom & Ågren
			Total...	37	149	19·9	80·1			
Bornholm-Basin	Bornholm Deep	96	Febr. 3 1905	402	37	91·6	8·4	13—31	90 f. Otter trawl	Strodtmann
	SE of Bornholm	76—77	» 7 »	391	44	89·9	10·1	13—39	—	—
	Bornholm Deep	93	» 18 1904	357	166	68·3	31·7	13—40	—	—
	SE of Bornholm	73—75	May 4 1905	41	11	78·8	21·2	15—33	—	—
	Bornholm Deep	95	» » »	230	9	96·2	3·8	13—35		—
	—	more than 90	» 28 1906	8	13	38·1	61·9	17—38	50 f. Otter trawl	Trybom & Swenander
	—	95	July 18—19 1908	166	34	83·0	17·0	20—40	—	Trybom & Övergaard
	ESE of Nexø	73	» 30 1907	9	5	64·3	35·7	18—27	—	A. C. Johansen
	Bornholm Deep		August 4 1906	171	27	86·4	13·6	16—36	—	Trybom & Övergaard
	—	96	» 8 1905	202	7	96·7	3·3	16—34	90 f. Otter trawl	Strodtmann
	—	97	» 20 1903	28	3	90·3	9·7	19—29	—	—
	—		Novbr. 6 1906	39	7	84·8	15·2	19—28	50 f. Otter trawl	Trybom & Nordquist
	—	95	» 7 1905	245	13	95·0	5·0	16—31	—	Trybom & Övergaard
	—	97—100	» 16 1902	30	0	100·0	0·0	14—24	—	Trybom
				36	14	72·0	28·0	24—34		
			Total...	2355	390	85·8	14·2	13—40		

VI. On a possible immigration of the youngest annual series of the plaice from the Kattegat and Belt Sea to the true Baltic.

As I have already stated (p. 4) Dr. PETERSEN thought that the renewal of the stock of plaice in the Baltic was carried on by a yearly immigration of quite young — about 1 year old — specimens either from the Kattegat and the Belts[1] or from the western Baltic[2]. The circumstance that I of late years have succeeded in showing that an immigration on a large scale of young partly of less than one

[1] Report IV of the Danish Biological Station. 1894.

[2] "Report XII of the Danish Biological Station. 1905", and "Ueber die in den Jahren 1904 und 1905 an den Küsten der Ostsee beobachtete Brut von Plattfischen". Rapports et Procès-verbaux. Vol. V. — Cons. perm. internat. 1906.

year old plaice takes place along the north coast of Jutland in an eastern direction and along the east coast of northern Jutland in a southern direction[1] tends again to call attention to Dr. Petersen's old idea of an immigration to the Baltic of young bottom stages of plaice.

It should however be remarked here, as I have already previously shown, that such differences in size exist between the specimens of the youngest series in the true Baltic and specimens of the same age in adjacent waters, that we must conclude that the majority of the specimens of every one of these series have grown up in the true Baltic — at least from the bottom stage. But as I have also emphasized, there is nothing to contradict the hypothesis that "some specimens may have immigrated as 0-Gr. and some as I Gr. etc.".

The 0-gr. of the plaice in the Baltic occurs mainly outside the beaches[2]. A small part of the stock is however found in shallow water near the coast, at any rate in certain years, and it holds good for these specimens in the western parts of the true Baltic that they are as large as specimens of the same age in the adjacent waters. Now it is by no means excluded that these specimens could have immigrated from the Kattegat and the western Baltic, but the investigations which I have hitherto carried on do not speak in favour of a supposition of an immigration.

Some Danish fishing experiments in the autumn of 1911 in Køge Bay (the true Baltic) showed that more young plaice than normally occurred in quite shallow water in this year. We thus got a chance to obtain a view of the character of the small stock, and to compare this with the contemporary stock in the Sound where unusually many specimens of the 0-gr. also occurred in 1911.

At four stations between Elsinore and Copenhagen we captured on September 18th at 1—2 meters depth with young plaice trawl 881 plaice of the 0-gr. and 3 plaice of the I gr. Work was done at each station for one hour.

At five stations in Køge Bay between Copenhagen and Stevns at 1—2 meters depth, we caught on 20. and 21. September 1911 61 plaice of the 0-gr. and no older specimens. At four of the stations work was done for one hour, at one station for three quarters of an hour.

In the beginning of November 1911 the experiments were repeated[3]. Fishing experiments were carried on between Elsinore and Copenhagen on November 2nd and 3rd at quite the same stations, with the same duration of hauls and at the same depth. Only 167 specimens of the 0-gr. were captured, 17 specimens of the I gr. and 1 specimen of the III gr. Moreover we made fishing experiments between 2—6 meters, but the bottom was only in one place fit for this kind of investigation, and nothing was captured. In Køge Bay between Copenhagen and Stevns fishing experiments were carried out on November 10th and 11th at three of the former stations, in all for 3 hours at 1—2 meters depth. Only 12 specimens of the 0-gr. were captured. There we fished moreover for four hours at depths between 2 and 6 meters, where 27 specimens of the 0-gr. were caught, but the bottom was only in one place adapted to this kind of investigations. The size of specimens in the two series of experiments was as follows:

[1] A. C. Johansen: Bericht über die dänischen Untersuchungen über die Schollenfischerei etc. Medd. Komm. f. Havunders. Ser. Fiskeri Bd. III No. 8. 1910.

[2] A. C. Johansen: Contributions to the biology of the Plaice IV p. 17.

[3] In the fishing experiments at depths between 1—2 meters in the Sound on September 18th 1911, 220 specimens of the 0-gr. were captured on an average per hour. On November 2.—3. the capture per hour of the 0-group was only 42 specimens. In Køge Bay the experiments showed on September 20—21 an average capture of 13 specimens per hour, whilst the experiments on November 10.—11th only showed a capture of 4 specimens per hour.

The far lesser capture in November must presumably be ascribed to two factors:

1) That the plaice when the water begins to be cold show a tendency to migrate into deeper water (this factor is probably the principal one in this case).

2) That the plaice when the water becomes colder squeeze themselves hard into the bottom and consequently are difficult to catch.

Øresund

	September 18th 1911 1—2 meters (4 hours fishing)	November 2.—3. 1911 1—2 meters (4 hours fishing)
0-Gr.		
3 cm	21 Indiv.	1 Indiv.
4 -	51 —	13 —
5 -	88 —	19 —
6 -	150 —	25 —
7 -	189 —	25 —
8 -	205 —	39 —
9 -	144 —	20 —
10 -	30 —	18 —
11 -	3 —	7 —

I Gr.

	♀	♂	♀
14 cm	1 Indiv.	- Indiv.	2 Indiv.
15 -		2 —	1 —
16 -	1 —	2 —	2 —
17 -	1 —	1 —	2 —
18 -		1 —	1 —
19 -			1 —
20 -			1 —
21 -			1 —

III Gr.

25 cm	1 Indiv.

Køge Bay

	20.—21. September 1911 1—2 meters ($4^3/_4$ hours fishing)	10.—11. November 1911 a) 1—2 meters (3 hours fishing)	b) 2—6 meters (4 hours fishing)
0-Gr.			
6 cm	1 Indiv.	- Indiv.	- Indiv.
7 -	9 —	1 —	- —
8 -	29 —	3 —	8 —
9 -	18 —	5 —	8 —
10 -	4 —	3 —	8 —
11 -			3 —

It is a characteristic feature that the size of the specimens is very similar in the two different periods inside each of the two areas, but deviates materially when we pass from one area to the other.

In the Sound on September 18th the average size (of 881 specimens) was 7·04 cm, the range of variation from 3—11 cm. and the standard deviation $\sigma = 1{\cdot}65$ [1].

In the Sound on November 2.—3., the average size (of 167 specimens) was 7·33 cm, the range of variation from 3—11 cm and the standard deviation $\sigma = 1{\cdot}91$.

In Køge Bay on September 20.—21. the average size (of 61 specimens) was 8·25 cm, the range of variation from 6—10 cm and the standard deviation $\sigma = 0{\cdot}84$.

In Køge Bay on November 10.—11. the average size (of 39 specimens) was 9·1 cm, the range of variation from 7—11 cm and the standard deviation $\sigma = 0{\cdot}98$.

We have thus every reason to suppose that the specimens which existed in Køge Bay in September had at any rate not recently immigrated from the Sound, and it is far more probable that the specimens which were caught in Køge Bay in November belonged to the same stock which was there in September, than that they should have immigrated from the Sound.

[1] The standard deviation is here calculated from the formula

$$\sigma = \pm \frac{1}{n} \sqrt{n \Sigma p a^2 - (\Sigma p a)^2}$$

where n = the total number of specimens
a = the deviation of a variate from the starting point for the calculation of the mean value
p = the number of variates in the different classes.

It is also worth while mentioning that several specimens of the I gr. were caught in the fishing experiments in the Sound both in September and November, while no specimen of the I gr. was caught in any of the experiments in Køge Bay.

A comparison with Table I (p. 9) shows that the specimens of the I gr., which were caught in the Sound, are considerably bigger than the main stock of the specimens of the same age in the true Baltic. The stock of the I gr. in the true Baltic is evidently not renewed to any essential degree by immigration from the Sound, as little as by immigration from the western Baltic[1].

VII. Concluding remarks.

In the present state of the investigations I can recapitulate my opinion concerning the question, how far the stock of plaice is indigenous to the true Baltic or has immigrated from the Kattegat and Belt Sea in the following way:

1) No single valid proof has been procured, and we have not even a single fact to support the hypothesis — that the migrations of the bottom stages of plaice from the Kattegat and Belt Sea to the true Baltic take place on a far larger scale than the migrations in the opposite direction.
2) The marking experiments in the Kattegat and the Belt Sea have elucidated that migrations of grown up plaice do not take place to any great extent from these waters to the true Baltic.
3) There are such differences in size between the majority of the specimens of the younger annual series (0 gr. and I gr.) in the true Baltic and specimens of the same age in the adjacent waters, that we can safely conclude that the majority of the specimens of these series have lived in the true Baltic at least from the youngest bottom stage[1].
4) We have reason to suppose that the current carries more plaice larvæ into the true Baltic from the Kattegat and Belt Sea than in the opposite direction[1], but there can be no doubt that the majority of the plaice larvæ which have been found in the true Baltic have also been hatched in this sea.

On the basis of the material to hand, we are not yet able to calculate approximately the percentage of the daily waste of eggs and larvæ of plaice in the western Baltic and the true Baltic[2].

The practical importance of the question whether the main stock of plaice in the true Baltic is indigenous to this sea or if it has immigrated from the Kattegat and the Belt Sea, should be regarded in the light that we in the former case in the true Baltic shall feel inclined to establish a stronger legislative protection of the plaice than in the latter case, just as we shall regard the question concerning the protection of the stock of plaice in the true Baltic in a less intimate connection with the question concerning protection of the stock in the Kattegat and the Belt Sea.

[1] Conf. A. C. Johansen: Contributions to the biology of the Plaice IV. 1908.

[2] A treatise by Prof. Hensen: "Über die Bestimmung des Fischbestandes im Meer". Wiss. Meeresunters., N. F. Bd. 14 Abt. Kiel 1911, was received so late that I have not been able to pay regard to it in the preceding chapters of this paper. Prof. Hensen discusses in that treatise the value of the material brought forth by Apstein in respect to its fitness for use for the calculation of the waste of the fish eggs in the sea. He is of opinion that Apstein's material, although very valuable, does not afford a reliable basis in the said respect.

CONTENTS.

		Page
I.	**Introduction**	3
II.	**Dr. Reibisch's age determinations of the plaice**	5
III.	**Dr. Reibisch's evidence to show a migration of plaice from the Kattegat and the Belt Sea to the true Baltic**	10
	A. The supposed migrations of the plaice from the Kattegat through the Belts to the Western Baltic and from the Western Baltic to the true Baltic	10
	B. The supposed migrations of the plaice from the Kattegat through the Sound to the true Baltic	20
IV.	**Dr. Reibisch's evidence to show that the stated number of plaice larvæ in the true Baltic would not be sufficient for the renewal of the stock**	21
V.	**On the relative frequency of the individuals of the two sexes in the western Baltic and the true Baltic**	26
VI.	**On a possible immigration of the youngest annual series of the plaice from the Kattegat and Belt Sea to the true Baltic**	30
VII.	**Concluding remarks**	33

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